STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

EARL WARREN, Governor
C. H. PURCELL, Director of Public Works
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BULLETIN No. 53

SOUTH COASTAL BASIN INVESTIGATION

OVERDRAFT ON GROUND WATER BASINS

1947

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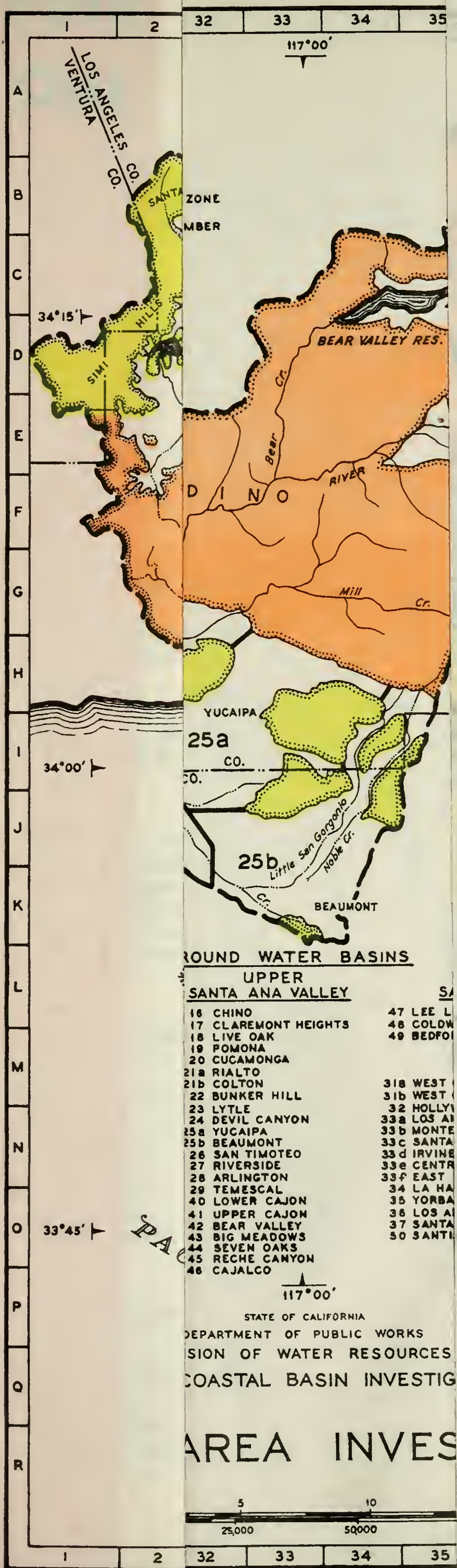

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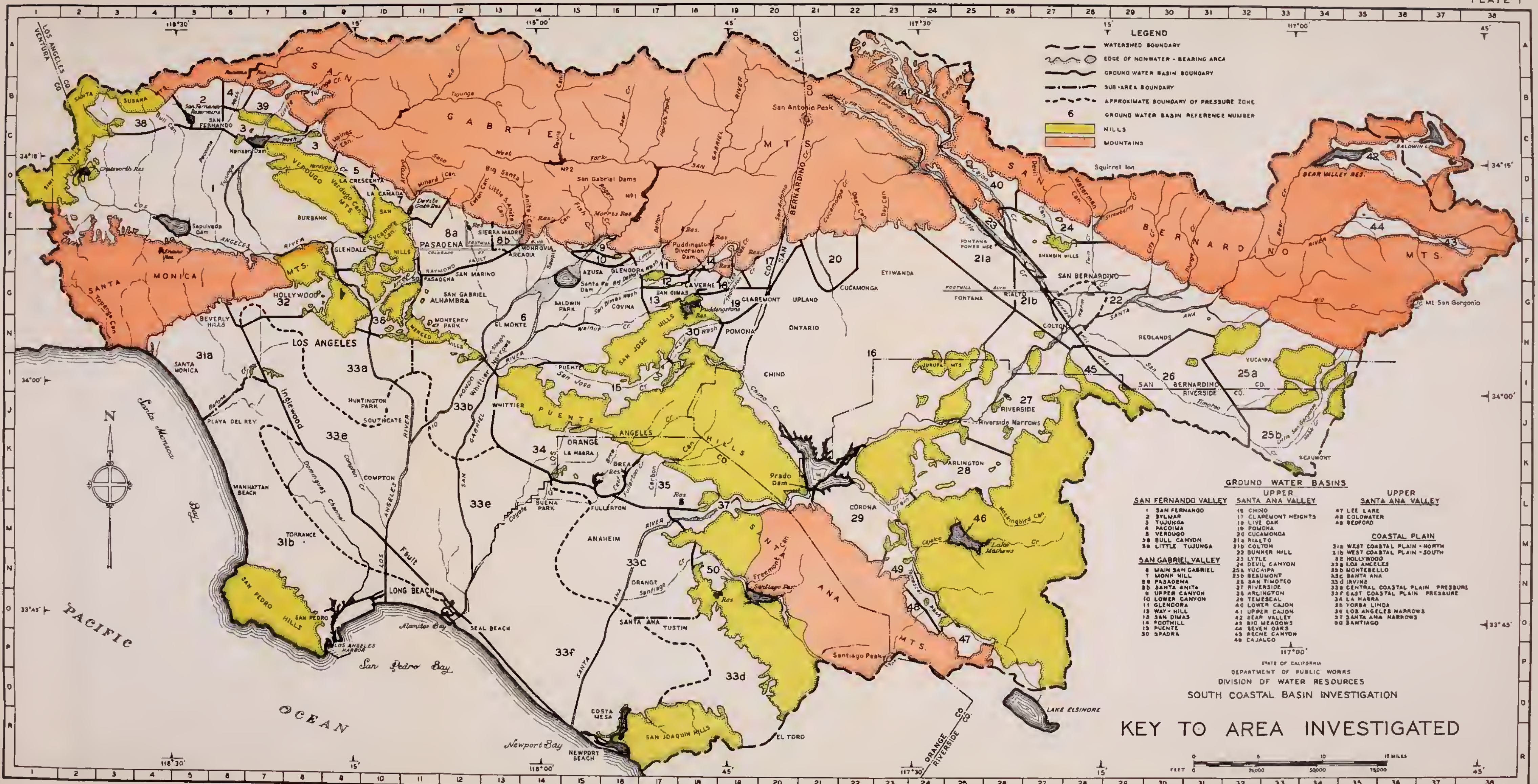

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ACKNOWLEDGMENT

Data used as a basis for the study of overdrafts presented in this bulletin were contributed by various departments of the federal, county and city governments, by flood control and water districts and by many companies and individuals.

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FOREWORD

This report is one of a series of bulletins covering various phases of the problem of water supply for South Coastal Basin. Within this area a rapidly expanding municipal development is now occupied by more than four million people, and about half of approximately 1,500 square miles of land suitable for production of high value crops is irrigated.

A large part of the water supply is pumped from the several ground water basins which underlie the area on which it is used. In some of these basins extractions have for several years exceeded net recharge. In this bulletin the overdrafts under present conditions on ground water basins within the drainage areas of Los Angeles, San Gabriel and Santa Ana Rivers are discussed and evaluated. Overdraft on the West Coastal Plain portion of South Coastal Basin is a matter left for later study and report, as is the rate at which present overdrafts may increase or new ones develop under the rapidly expanding demand on some of the basins.

Under any generally applicable procedure, the evaluation of overdraft requires that the effect of many factors be estimated and because of this an exact evaluation is impossible. Experience alone, with draft on the ground water reduced by the amount of the indicated overdraft, and allowance made for changes in mean supply, will tell how far the values presented herein differ from the true overdraft. In those cases where the derived overdraft is small there may actually be a small excess and vice versa. Where the derived value is large, however, corrective measures must be undertaken if increased pumping costs and eventual exhaustion of the stored supply are to be avoided. Every effort has been made to utilize available data and procedures in the estimates and it is believed that the values presented provide a reliable basis for whatever corrective measures are undertaken.

CHAPTER I. INTRODUCTION

DEFINITION OF OVERDRAFT

In all ground water basins discussed in the following pages the water table falls during dry periods, and in virtually all it rises when there is more rain, with alternating downward and upward trends, each continuing over periods of several years, and at some points resulting in over-all fluctuation of 200 feet or more. Outflow originating in the ground water of each basin varies to a greater or lesser degree with elevation of the water table in the basin.

Whenever average extractions during a cycle exceed net recharge,* water is drawn from storage, the water table falls, outflow is decreased and net recharge is correspondingly increased. In the next succeeding cycle, if extractions continue the same, the difference between net recharge and extractions, and consequently the net drop in water table elevation during that cycle, will be less. In some basins the relationship between water table elevation and outflow is such that a balance between net supply and present extractions can be attained within a reasonable period of time. In others the progressive drop in water table elevation must continue through many cycles. In still others, where the outflow is relatively small, the balance may be brought about only through a reduction in extractions.

Whether or not an overdraft exists in a particular case depends largely upon the point of view. From the standpoint of the user who pumps in an area where the water table fluctuates widely, or is far below ground surface, any added extraction which increases either fluctuation or pumping lift may constitute an overdraft. Another party, located near the point of outflow where both fluctuation and lift are small, may consider that lowering the water table results only in reduction in outflow, and hence, so far as he is concerned, in the amount of water wasted. An extreme viewpoint is that of the pumper who is in a position to economically extract the last water left in the basin, and who might, therefore, consider that no overdraft exists so long as he can pump what he needs, no matter how many others are forced to obtain water elsewhere. In order to be complete, the definition of overdraft as the amount by which extractions exceed net recharge, must, therefore, also indicate the conditions under which an overdraft is considered to exist.

In some ground water basins discussed herein, legal restrictions, large imported supplies, or limited storage capacities preclude the possibility of continuing overdraft. The remaining basins fall in two categories: first, those in which outflow responds quickly to changes in water table elevation; and second, those in which appreciable change in outflow results only from large changes in elevation. The situation of each individual pumper has, of course, not been investigated in detail, but it is assumed that in none of the basins in the first category will unreasonable hardship result if the water table is permitted to reach the level

* Difference between supply to and outflow from the ground water.

at which net recharge balances present extractions. In these, therefore, no overdraft is considered to exist, and the long-time mean value of one or another item of supply and demand is estimated instead. For basins in the second category, where a balance can be attained only after long delay or extreme lowering of the water table, it is assumed that an overdraft exists if continuance of present extractions throughout a cycle of recharge will result in outflow from the ground water averaging less during the cycle than its historic average during the 11-year period, 1927-28 to 1937-38, inclusive. For basins in this latter category, overdrafts or excesses are calculated. Reasons for use of above 11-year period are discussed later.

PROCEDURE FOLLOWED

Several procedures have been devised for estimating overdraft, data available, and the physical situation in general, determining which is preferable in a particular instance.

Throughout South Coastal Basin, extractions, relatively few of which have been measured, are from a multiplicity of wells, and their evaluation without extensive work is subject to considerable error. If the overdraft is considered to be upon both surface and ground water supply, rather than upon the ground water alone, the difference between water leaving the area and that entering, rather than the difference between extractions from the ground water and supply to it, determines the amount of the overdraft. Precipitation, surface inflow, imports, consumptive use, surface outflow and exports, all of which are more easily evaluated, become the significant items, rather than percolation to the ground water and extractions from it.

When the demand in any basin exceeds the supply, water comes from underground storage to satisfy it. The average amount which must be supplied from storage annually, over a period of long-time mean supply, is the measure of the annual overdraft. This can be evaluated by correcting historic change in storage during any base period, for differences between base period and long-time mean values of the items of supply and demand. Throughout the portion of South Coastal Basin herein considered, both net changes in storage during the base period, and differences between base period and long time mean values of items of supply and demand involved, are relatively small. For this reason, the procedure based on the concepts, (1) that the overdraft is on the whole supply, and (2) that overdraft is measured by change in storage, is adopted for use in this report. It is discussed in greater detail in Chapter IV.

Because so many of the values used are small, and in the interest of an over-all check on the work, all values used in the calculations are presented to the nearest 10 acre-feet throughout the report. It is not intended to imply thereby that any such impossible accuracy is attained, and final results are summarized to the second significant figure only.

SUMMARY

The extent to which each ground water basin is considered an independent unit is largely a matter of judgment. In San Fernando Valley, where a large part of the supply available to a group of basins is from a common source outside the area, it is herein considered that the excess is available wherever needed within the City of Los Angeles, without regard to basin boundaries. In this case it would be difficult to justify any other assumption.

Along Santa Ana River from the mountains to the ocean, excluding Chino Basin and basins tributary to it, outflow from upstream basins responds quickly to changes in water table elevation, and the change from historic values required to bring about a balance between net supply and extractions is relatively small. It is therefore assumed that there is neither overdraft nor excess in these basins, but that the overdraft resulting from extractions throughout the system is on the Coastal Plain basins alone. In most of the upper basins, present extractions might be considerably increased without causing hardships within them, and so from one point of view, an excess is available in those basins. Reduction in outflow resulting from such increased draft would, however, decrease the supply to the Coastal Plain, and correspondingly increase the overdraft there. Total overdraft on the system is the same, no matter what distribution is assumed.

The portion of the San Gabriel River System which is unaffected by legal restrictions includes basins in both categories, those in which outflow responds quickly to relatively small changes in water table elevation, and those in which appreciable response requires large changes. The values of excess assigned to the latter are those with subsurface outflow averaging that of the 11-year period, 1927-28 to 1937-38, inclusive. So long as this excess is not utilized the water table will rise, and outflow slowly increase until it eventually balances the unused portion of the excess. This increase in outflow will add to the supply to Main San Gabriel Basin, and in turn to the outflow from it, and to the supply to Central Coastal Plain, reducing the overdraft there. Thus, even in a system of this character, the distribution of overdrafts and excesses is to a degree arbitrary, but total overdraft on the system is again unaffected by the distribution.

A significant change in outflow originating in the ground water of Chino Basin would require that the water table in the basin be either considerably higher or lower than it has been during the period in which levels have been measured and recorded. For this reason, the group which includes Chino Basin and basins tributary to it is considered separately from the remainder of the Santa Ana River System. All of these basins are considered as falling in the second category, and overdraft or excess is evaluated for each. Within all of the systems or groups herein discussed, the distribution of overdraft depends upon more or less arbitrary assumptions, not only as to subsurface or rising water outflow, already noted, but also as to interchange of water by other means. This is especially true in the Chino Basin Group, where extensive spreading operations in the tributary basins reduce the surface flow to Chino Basin, but make available to it a greater imported supply. So long as these assumptions apply only to interchange of water between basins within the group, they too affect the distribution, but again do not affect total overdraft on the group.

Estimated total annual overdrafts on or excess supply available to the four systems of basins are presented below. Overdrafts or excesses evaluated for individual basins are summarized in Table 5.

Ground Water System	
Los Angeles River above the Narrows	25,000 acre-feet excess*
San Gabriel River	10,000 acre-feet overdraft
Chino Basin Group	21,000 acre-feet overdraft
Remainder of Santa Ana River System	14,000 acre-feet overdraft

* Includes water available to Los Angeles Aqueduct in Mono Basin and Owens Valley. See discussion of excess in San Fernando Valley Area in Chapter VI.

CHAPTER II. DESCRIPTION OF SOUTH COASTAL BASIN

TOPOGRAPHY

South Coastal Basin [1] includes about 3,800 square miles of area tributary to Los Angeles, San Gabriel and Santa Ana Rivers,[2] and to smaller streams and drains entering the Pacific Ocean along approximately 65 miles of southeasterly trending shore line between Topanga Canyon and Newport Bay, and occupies portions of Los Angeles, Orange, Riverside and San Bernardino Counties, in California, south of the crest of San Gabriel and San Bernardino Mountains.

The mountain ranges,[3] which occupy the northerly 1,100 square miles of the basin, attain elevations in excess of 10,000 feet at San Antonio Peak in the San Gabriels a short distance west of Cajon Pass, and at Mount San Gorgonio, in the San Bernardinos not far from the easterly basin boundary. Each of the ranges is lower in its westerly portions.

San Fernando, San Gabriel and Upper Santa Ana Valleys, drained by Los Angeles, San Gabriel and Santa Ana Rivers, respectively, border the south slope of the mountins.

South of these valleys a range, intermediate between the high mountains and the coast, crosses the area in a southeasterly direction from Santa Monica Mountains to Santa Ana Mountains, both of which form a part of the intermediate range. Santa Monica Mountains reach an elevation of a little more than 2,000 feet. Santiago Peak in the Santa Anas is over 5,000 feet high. San Rafael, Merced and Puente Hills, which lie between, are much lower. The three principal streams cut through the intermediate range at Los Angeles Narrows, Whittier Narrows and Santa Ana Narrows, respectively.

At the westerly extremity of San Fernando Valley, Simi Hills extend northerly from Santa Monica Mountains to Santa Susana Mountains, and form the divide between Los Angeles River drainage and that into Santa Clara River, which flows into the ocean far to the west of South Coastal Basin. Between the three inland valleys wide spurs extend northward from the intermediate range, virtually separating the valleys one from the other. Lying northeasterly from Santa Ana Mountains, and separated from it only by the narrow valley of Temescal Creek, a large triangular block of low granitic hills extends to the vicinity of Colton, only about 10 miles from San Bernardino Mountains. The northerly trending crest of this block forms a part of the divide between drainage directly into Santa Ana River, and that into San Jacinto River above Lake Elsinore, which latter area is excluded from discussion in this bulletin. Beyond the northern tip of the granitic block the divide trends a little south

[1] "Basin" is used here in its geographic sense. South Coastal Basin includes not only many "ground water basins," but also their tributary nonwaterbearing hill and mountain drainage. A "ground water basin" includes the water-bearing deposits only.

[2] Lake Elsinore fills and overflows into Temescal Creek, and thence into Santa Ana River very infrequently. The overflow constitutes so small a part of the inflow that the area tributary to the lake is not included as a part of Santa Ana River drainage.

[3] For a more detailed description of these mountains, as well as the rest of the area, see Division of Water Resources Bulletin 45, "South Coastal Basin Investigation—Geology and Ground Water Storage Capacity of Valley Fill," 1934.

of east, paralleling San Timoteo Creek to the vicinity of Beaumont. Between Beaumont and the San Bernardino Mountains the boundary crosses Beaumont Plains, northerly along the crest of a flat divide between drainage into Santa Ana River by way of San Timoteo Creek, and that into Salton Sea, far to the southeast.

The Coastal Plain lies between the south face of the intermediate range and the ocean. About midway of the shore line between Topanga Canyon and Newport Bay, San Pedro Hills form the outer end of a promontory jutting into the ocean. To the west of these hills the shore line trends only a little west of north, to the point where it meets the south toe of Santa Monica Mountains. For convenience, this northerly trending shore line is called the West Coast. East of San Pedro Hills the trend is first northeast, then changes gradually to southeast at Alamitos Bay, and continues in a relatively straight course to its contact with the hills southeast of Newport Bay. This portion is called the South Coast. The southeast boundary of the Coastal Plain follows the divide between drainage into Newport Bay, and that into several relatively small streams which enter the ocean farther south and east. Save for a short distance in the vicinity of El Toro where it crosses a flat saddle, it follows the crest of San Joaquin Hills. North of the saddle it enters the foothills of Santa Ana Mountains.

South Coastal Basin as a whole constitutes a distinct hydrologic unit. Natural inflow of water originating outside the area is limited to infrequent and negligible overflow from Lake Elsinore, and possibly a very small underflow at the few points where the boundary crosses alluvium. The same is true of areas included in or draining into each of the three inland valleys. The Coastal Plain however is different, in that a considerable part of its supply originates in or passes through the three inland valleys, and is therefore affected by conditions in the valleys.

The area of mountain, hill and valley land included in each of the four main divisions of South Coastal Basin is shown in Table 1.

TABLE 1. AREAS OF VALLEY AND FOLDED, AND HILL AND MOUNTAIN LAND IN FOUR MAIN DIVISIONS OF SOUTH COASTAL BASIN

(Square Miles)

Division	*Valley and folded lands* *	*Tributary lands*		*Total*
		Hills	*Mountains*	
San Fernando Valley	209	74	216	499
San Gabriel Valley	201	46	334	581
Upper Santa Ana Valley	670	267	553	1,490
Coastal Plain	852	232	138	1,222
Total	1,932	619	1,241	3,792

* Topographically, a large part of the folded area might be classed as hills, but since it is water-bearing it is treated as a unit with valley lands.

Topographically, the mountains are steep and rugged, and the hills more gently sloping and rounded.

A large part of the Coastal Plain is relatively smooth, with a gentle slope generally at right angles to the shore line. However, adjacent to San Joaquin Hills on the southeast, and to the intermediate range which borders the plain on the north and northeast, the slope steepens and topography is more rolling. Along the West Coast, low, irregular sand dunes form the surface.

In San Fernando and San Gabriel Valleys a comparable situation exists. The slopes, which are generally to the south, are a little steeper throughout than those on the Coastal Plain, and increase as they approach the mountains to the north. In spite of this increase in slope and somewhat rougher topography immediately adjacent to the mountains, change at the contact between mountains and valley is abrupt. By far the larger parts of both valleys are less than 1,000 feet above sea level. However, along the northerly edge of La Canada Valley, at the extreme northwesterly corner of San Gabriel Valley, an elevation of 2,000 feet is reached.

All that portion of Upper Santa Ana Valley which lies northwest of Santa Ana River and west of San Bernardino, comprising more than half the area, has surface characteristics similar to San Fernando and San Gabriel Valleys. Slope is generally to the south, and is steeper in the vicinity of the mountains. East of San Bernardino that portion of the area which represents the debris cones of Santa Ana River and of Mill Creek slopes directly to the west, the steeper portion lying in the vicinity of the canyon mouths. South and east of this area the land rises rather abruptly several hundred feet to Yucaipa Valley and Beaumont Plains. The westerly portion of Upper Santa Ana Valley ranges in elevation above sea level from 500 feet at Santa Ana Narrows, to about 2,500 feet along the base of San Gabriel Mountains north of Etiwanda. Where San Timoteo Creek leaves Yucaipa Valley the elevation is about 2,000 feet, at Beaumont 2,500 feet, and at the extreme northeast corner of the valley about 10 miles north of Beaumont it is over 5,000 feet.

Throughout the three inland valleys and the Coastal Plain the topography suggests the origin of present surface materials, debris cones, which are especially well defined near the mountains, covering most of the area.

CLIMATE

The climate of South Coastal Basin is marked by a relative uniformity of temperature, and wide variation in precipitation both areally and in point of time.

With elevations ranging from sea level up to 5,000 feet in the valley area, and up to more than 10,000 feet in the mountains, there is of course some variation in temperature. At Los Angeles, 14 miles from the ocean, at elevation 300, mean temperature is 63 degrees F., ranging from 28 degrees to 109 degrees. At Riverside, about 38 miles from the ocean, at an elevation of 900 feet, it averages 63 degrees, with an extreme range from 21 degrees to 118 degrees. At Squirrel Inn, near the crest of San Bernardino Mountains north of San Bernardino at an elevation of 5,700 feet, the mean is 52 degrees, the minimum 7 degrees below zero, and the maximum 99 degrees above. Some snow falls in the mountains almost every year, with occasional moderately heavy coverage in higher portions. In the valleys mean temperature varies little from place to place, but the range between extremes is greater inland than along the coast. Throughout the greater part of the valley area damaging frosts occur for short periods only, and only rarely are they so severe that heating will not prevent loss of semitropical crops.

Mean annual precipitation varies from about 12 inches along the coast, to 50 inches near the crest of the mountains. Near Riverside, where Santa Ana Mountains interfere with normal movement of air from the ocean toward the high mountains to the north, mean annual precipitation is only 11 inches. This may be compared with 25 inches at about the same elevation in San Gabriel Valley, where there is relatively little interference from the low hills which bound it on the south.

From the standpoint of utilization, the large variation in precipitation from season to season and from year to year is most significant. If annual precipitation were uniform, and occurred during the growing season, little irrigation would be required to produce virtually the same crops now grown. There has been, however, a year in which precipitation at Los Angeles was only 37 percent of normal, a period of three consecutive years in which it averaged only 46 percent, and a period seven years in length during which it averaged 65 percent. This, together with the fact that on the average only 16 percent of the annual total falls during the principal growing season, April to October, inclusive, makes irrigation necessary for nearly all crops, on all but the most retentive of soils.

SOILS

Fertility, and other characteristics which determine suitability of its soils for various uses, influence the type and extent of culture which develops on an area. Permeability of the soils is one of the factors which determines what part of precipitation and water applied on the surface flows off immediately, what part is retained near the surface for use by vegetation, and what part continues downward and eventually joins the ground water.

In this brief discussion of soils covering South Coastal Basin, nomenclature adopted by the Bureau of Soils of the United States Department of Agriculture, from whose publications the information was obtained, is used. The soils are grouped in four provinces, i.e. residual, older alluvial, recent alluvial and wind laid. Geologically, of course, all of these soils are recent.

Residual soils are formed in place from weathering of the parent rock, which may be either crystalline basement complex, or very old consolidated sedimentary deposits. These soils are classified by the Bureau of Soils only where topography, and surface conditions in general, are suitable for agriculture. Older alluvial soils are formed in place from old valley filling material, which has been undisturbed for a period sufficiently long for significant weathering to occur. In a sense they also are residual, but the parent material is unconsolidated. Soils of this province lie outside the path of, and at generally higher levels than present day streams. Recent alluvial soils are formed by deposition of material lately eroded from exposed bedrock, or from soils of either of the other provinces. Because of frequent disturbance of the surface, weathering since deposition has been limited. While some movement of recent alluvial soils through wind action is general in South Coastal Basin, deposition in sufficient quantity to justify its classification as wind laid soil is confined to a few small areas. Each of these provinces includes several series, the classification being largely on the basis of color, subsoil characteristics, and nature of parent materials. Each series in turn is further split up into types, largely on the basis of texture.

The soil type in a particular series of the residual province depends primarily upon the stage of weathering, and this factor also has a material bearing on the texture of soils in the older alluvial province. Soils of the recent alluvial province, however, are little changed since first laid down, and for this reason the relationship between location and texture is generally well defined. As a stream decreases in velocity upon entering the valley from the mountains, it drops the heavier portions of its load first, so that large rocks are characteristic of alluvium near the mountains. Material from a particular source carried down in a particular flood grows progressively finer with distance from the mountains. Because of wide variation in flow, both as between adjacent streams and between floods on the same stream, irregularities exist, but in each series of recent alluvial soils the coarser textured occur in the higher portions near the mountains. The Hanford series, which includes many types ranging from stony, sandy loam to silty clay loam, has wide distribution from the mountains to the ocean. The Chino series, on the other hand, includes only four types, all very fine, and all of which lie far distant from the mountains.

Virtually all soils covering San Fernando Valley are of the recent alluvial province, with only a few small areas of older alluvial soils around the border of the valley. In the westerly half of the valley the Yolo series predominates, and in the easterly half the Hanford and Tujunga. The Yolo series originates in the sedimentary and metamorphosed sedimentary mountains and hills surrounding the westerly portion of the valley, and the soils are generally less gravelly and finer textured than those of the Hanford and Tujunga series, which are derived from the harder crystalline rocks of San Gabriel and Verdugo Mountains, and have generally been transported by larger streams. All of these soils are valuable for some form of agriculture, the variety of crops for which the more gravelly types of the Hanford and Tujunga series are suitable being restricted to those least affected by tillage difficulties. Fortunately, tree crops, particularly citrus, grow best on higher, more steeply sloping, rockier portions of the valley, because of more favorable climatic conditions there. Relatively small areas of usable residual soils cover the hills around the westerly and southerly portions of the valley. These soils are generally heavy.

In San Gabriel Valley the major portion of the area is likewise covered by soils of the recent alluvial province, the greater part being of the Hanford series. For a considerable distance above Whittier Narrows, and throughout San Jose Valley, the generally fine, silty and sometimes adobe-like soils of the Chino series occur in considerable amounts. These are of value for culture of garden crops, because of their texture, and because of the regularity of accompanying surface topography. Soils of the Yolo series cover considerable areas in San Jose Valley, and appear in lesser amounts elsewhere throughout San Gabriel Valley. In the portion of San Gabriel Valley lying west of Eaton Wash, soils of the Ramona series of the older alluvial province predominate. These have been formed by weathering of long undisturbed sedimentary deposits, which long ago originated in crystalline rocks of the mountains to the north. These soils are generally heavier and more compact than those of the recent alluvial province, but where tillage is not made too difficult by the presence of partially decomposed rocks and gravel, or by an excessive amount of clay, they are valuable for agriculture because of their fertility and moisture holding characteristics. The more rocky and gravelly types of this series nearly all underlie the cities of Pasadena, South Pasadena, San Marino and Alhambra, so their suitability for agriculture is not a matter of great moment. Soils in the eastern portion of the valley north of San Jose Hills are about equally divided between the Hanford and Ramona series. Here both are excellent for the production of citrus. Considerable areas of heavy residual soils, at present dry-farmed, and in part susceptible to irrigation, cover portions of San Rafael, Puente and San Jose Hills.

In Upper Santa Ana Valley, as is true in San Fernando and San Gabriel Valleys, soils of the recent alluvial province, primarily of the Hanford and Tujunga series, but including also considerable areas of the Yolo series in the vicinity of Corona, and of the Chino series in the vicinity of Chino, predominate. As elsewhere, these are rocky and gravelly near their sources, and grade to finer types lower in the valley. Along the entire southeasterly boundary, however, including Yucaipa Valley and Beaumont Plains, soils are mostly of the older alluvial province, partly Ramona, but more extensively of the Placentia series. The latter grades in type from gravelly loam to clay loam, and since part of it was not moved far from its original source prior to weathering, and the stage of weathering varies widely from place to place, there is no such definite relation between type and location as is true of recent alluvial soils. In spite of the fact that some types of this series are difficult to work, and are lacking in fertility, citrus is raised successfully on a large part of it. North of Santa Ana River, just above Santa Ana Narrows, is a considerable area of Antioch soils. These are generally heavy, poorly drained, and of irregular topography, and are therefore not very well adapted to agriculture. In the vicinity of Rialto and Colton there are about 3,000 acres of Oakley sand, the only type representing the wind laid province in the area. This soil is derived largely from Hanford sand, and while subject to movement, the dunes are generally more rounded than those which occur along the coast. When held in place this soil will support crops, but is not considered especially valuable for agriculture. Overlying the lower slopes of granitic hills which protrude above the alluvium on either side of Santa Ana River below Colton, and covering a large part of the irregular surface south of Riverside and Arlington Valleys, are various types of the residual Holland and Sierra series. The two series are distinguished on the basis of color, the former being generally brown, the latter red. Both are gritty throughout, with light textured surface soil grading through heavier subsoil to partially disintegrated granite at a depth of from two to six feet. The subsoil is hard and compact when dry, and if exposed tends to form hardpan. Where deep, these soils are fairly retentive of moisture, but dry out quickly where shallow. Humus is lacking and fertility is low.

On those extensive portions of the Coastal Plain which have in comparatively recent times been periodically flooded by the larger streams, Hanford and Chino soils predominate. Recent soils deposited by smaller streams from the sedimentary hills are principally of the Yolo series. Bordering the hills, and throughout the area between Inglewood Fault and the ocean, there are large areas of older alluvial soils, principally

Ramona, but with a considerable area, too, of the similar but a little more pervious Pleasonton series, and a quite extensive deposit of Montezuma clay adobe about midway between Inglewood Fault and the West Coast. This last named soil is very fertile, and because it is highly retentive of moisture is suitable for dry farming. With irrigation, various berry crops are especially profitable. Heavy types of the residual Altamont and Diablo series cover the more gently sloping portions of hills surrounding the Coastal Plain. These soils are generally fertile and moisture retentive. Because of tillage and irrigation difficulties, they are most useful for dry farming. Between Playa del Rey and San Pedro Hills a deposit of Oakley fine sand of the wind laid province extends inland from two to five miles from the ocean. The surface is undulating, making irrigation difficult, and this, together with relatively low fertility of the soil, results in its use primarily for production of specialized dry-farmed crops. A perched water table lies near the surface over the lower portion of the Coastal Plain. As a result, drainage is resorted to in order that alkali may not destroy or reduce productivity of the soil. Tidal swamps and beach sands, suitable for no agricultural use, cover only a small area along the coast.

CULTURE

In a semiarid region like South Coastal Basin the type of natural vegetation which develops depends in a large measure upon the water supply available. In swampy areas where supply is unlimited, a heavy growth of plants which transpire large amounts of water flourishes. In areas where the water table is far below the surface, and the supply available to plants is limited to that which can be stored in the root zone and carried over from the rainy season to the growing season, the type of natural vegetation depends upon the amount so stored. Where precipitation is so small that it seldom penetrates more than a very few feet, shallow rooted plants which require little water develop. Where penetration from a greater amount of rainfall is consistently greater, deeper rooted plants eventually predominate in the area. Generally, that type develops which will use virtually all of the precipitation which does not evaporate, run off or penetrate below the soil mantle in which root growth is possible.

In South Coastal Basin a heavy growth of brush covers most of the mountains, with a few small stands of conifers at higher altitudes, and water-loving trees along streams in canyon bottoms. Higher hill and valley areas, where uncultivated, are also brush covered, while grass and weeds predominate on those that are lower. In the extreme lower portions of some basins a high water table supports a dense growth of water-loving vegetation.

Factors other than precipitation, such as temperature, topography, soil characteristics, transportation facilities and cost of developing the required water supply, influence the type of artificial culture which replaces natural vegetation. A large part of the valley lands of South Coastal Basin, particularly of the Coastal Plain, San Fernando Valley and San Gabriel Valley, is occupied by some type of culture requiring, in this climate, the application of water in addition to precipitation. Approximately one-half of Upper Santa Ana Valley is so occupied.

The cities of Los Angeles, Santa Monica, Long Beach and numerous smaller towns occupy a large part of the Coastal Plain west of San Gabriel River. Farther east are the cities of Santa Ana, Orange, Anaheim and Fullerton, which together cover considerable ground but do not dominate the area. The cities of Glendale and Burbank, in the easterly end of San Fernando Valley, adjoin Los Angeles on the north. To the northeast the cities of Pasadena, South Pasadena, San Marino, Alhambra, Monterey Park, San Gabriel, El Monte, Arcadia, Monrovia and Sierra Madre occupy most of San Gabriel Valley lying west of San Gabriel River. Smaller municipal developments are scattered over the remainder of the two valleys, being more numerous and closer together in San Fernando Valley. In Upper Santa Ana Valley urban development occupies about 10 percent of the total area, as compared with about 35 percent in each of the other two interior valleys, and nearly 40 percent on the Coastal Plain. The larger part is concentrated in the cities of San Bernardino, Colton and Riverside, most of the remainder being in Pomona and Ontario, near the westerly edge of the valley, and Redlands, some eight miles southeast from San Bernardino.

Outside the municipalities, citrus generally dominates the higher portions of the three inland valleys and the Coastal Plain. This is a high value crop, which justifies the use of expensive water, and can be profitably grown on the gravelly soils and steeper topography found there. Then too, the higher, sloping areas are generally more frost-free than the flatter, lower lands. This is not true of Yucaipa Valley and Beaumont Plains, at the easterly extremity of Upper Santa Ana Valley, and very little citrus is raised there. In that area deciduous fruits are the dominating irrigated crop, and a considerable part of the area is still undeveloped. Elsewhere in South Coastal Basin the principal deciduous crop is walnuts, and it generally occupies lands somewhat lower than the citrus belt. Grapes, which occupy a considerable acreage of land in upper Santa Ana Valley upon which citrus might be grown, are irrigated very little, so cost of water is not there a governing consideration. Lower portions of each of the interior valleys and the Coastal Plain, where cultivated, are generally occupied by garden and field crops and alfalfa. This may be attributed to the suitability of the finer textured, level lying soils, the economy with which water can be developed, and the relative unimportance of frost in the culture of annual crops.

Throughout South Coastal Basin the area of valley land, not now occupied by municipal development, upon which some form of agriculture cannot be practiced is comparativly small. The greater part of the unusable land is on or near washes, where soil is subject to overflow, and is principally boulders in the upper reaches, and sand farther downstream. There are also a few areas where a high water table produces alkali. In those relatively small areas where cost of a water supply is prohibitive even for citrus, grapes can generally be grown without irrigation. In general, soils suitable for the lower valued crops overlie areas from which an inexpensive water supply can be developed.

While hill lands are generally better suited to domestic development or dry farming, a considerable area on hills east of Whittier and south of Puente is devoted to citrus and avocados. The mountains are in general so rugged as to make unprofitable any occupancy other than recreational.

The acreage covered by each type of development is presented in Table 2, and in Chapter VI where individual basins are discussed. A map showing distribution, by types, as of 1932, is presented in an earlier bulletin * of the Division of Water Resources.

TABLE 2. AREAS OF CULTURE IN FOUR MAIN DIVISIONS OF SOUTH COASTAL BASIN[a]

Crop	*Acres* 1932	*Acres* 1942
San Fernando Valley		
Garden and field	21,000	22,000
Avocado and citrus	10,000	12,000
Deciduous	15,000	12,000
Alfalfa	7,000	7,000
Irrigated grass	1,000	1,000
Domestic and industrial	31,000	39,000
Total	85,000	93,000
San Gabriel Valley		
Garden and field	10,000	9,000
Avocado and citrus	31,000	31,000
Deciduous	19,000	13,000
Alfalfa	2,000	3,000
Irrigated grass	2,000	2,000
Domestic and industrial	33,000	41,000
Total	97,000	99,000
Upper Santa Ana Valley		
Garden and field	26,000	27,000
Avocado and citrus	80,000	82,000
Deciduous	27,000	25,000
Alfalfa	12,000	12,000
Irrigated grass	8,000	10,000
Domestic and industrial	33,000	37,000
Total	186,000	193,000
Coastal Plain		
Garden and field	99,000	100,000
Avocado and citrus	88,000	93,000
Deciduous	14,000	8,000
Alfalfa	12,000	13,000
Irrigated grass	6,000	7,000
Domestic and industrial	179,000	200,000
Total	398,000	421,000

[a] Includes culture on mountains and hills adjacent to valley, but excludes more distant recreational development.

STREAM SYSTEMS

As has been stated, all that portion of South Coastal Basin which lies north of the intermediate range is drained by the Los Angeles, San Gabriel and Santa Ana River stream systems. A part of the Coastal Plain is tributary to these streams, and a part drains directly to the ocean. The areas triutary to each are shown in Table 3.

* Bulletin No. 43, South Coastal Basin Investigation, "Value and Cost of Water for Irrigation," 1933. Plate A.

TABLE 3. AREAS OF SOUTH COASTAL BASIN DRAINED BY STREAM SYSTEMS
(Square Miles)

	Los Angeles River	*San Gabriel River*	*Santa Ana River*	*Small streams tributary to the ocean*	*Total*
Above the intermediate range					
Mountains	393 [a]	163	546	0	1,102
Hills	78	48	260	0	386
Valley and folded	314	114	656	0	1,083
Subtotal	785	325	1,462	0	2,572
Coastal plain					
Mountains	0	0	67	72	141
Hills	27	55	57	94	233
Valley and folded	128	222	53	445	846
Subtotal	155	277	177	611	1,220
Entire area					
Mountains	393 [a]	163	613	72	1,241
Hills	105	103	317	94	619
Valley and folded	442	336	709	445	1,932
Total	940	602	1,639	611	3,792

[a] Includes 116 square miles tributary to San Gabriel River above the point where Rio Hondo branches off.

One characteristic common to all principal streams of South Coastal Basin is that they are dry throughout a large portion of their length during most of every year. This is due in part to absorption in gravels underlying their channels, and in part to diversion to offstream spreading or use. After leaving the mountains the only reaches in which flow is continuous throughout the year are those crossing areas where the water table is high enough so that rising water results. How far downstream this rising water continues to flow depends upon the amount of diversion from it, and the absorptive characteristics of the channel below the area of high water table. During some part of all but the driest years, however, most of the streams are continuous from the mountains to the ocean, the amount of this flood discharge, and the length of time during which it flows depending upon wetness of the season, intensity of storms, operation of regulatory reservoirs on upper reaches, distance of flow across valley fill, and unit rate of percolation into the valley fill.

Los Angeles River originates in low hills and mountains bordering the westerly portion of San Fernando Valley, flows easterly about 20 miles along the depression near the south edge of the valley, cuts through the intermediate range at Los Angeles Narrows, trends southerly for about 30 miles across the Coastal Plain, and enters the ocean at Long Beach. In all this length, significant percolation opportunity exists in the upstream eight miles only. Throughout the lower 12 miles in San Fernando Valley the water table is at or above the stream-bed. Through the Narrows, and across the greater part of the permeable area just below, the channel is paved. Between the paved section and Inglewood

Fault, the Coastal Plain is underlain near the surface with an almost continuous clay cap. Thus, not only flood water which reaches the river, but rising water which originates above the Narrows is nearly all carried to the ocean. Operation of Sepulveda Reservoir, 11 miles upstream from the Narrows, reduces peak flows, but has little effect on total discharge.

While several small streams draining the north slope of Santa Monica Mountains contribute to flood flow of the stream, the principal tributaries in San Fernando Valley enter from the north. All of these flow eight miles or more across the alluvium before reaching the river. The largest, Tujunga Creek, drains about 133 square miles of mountains, ranging in elevation from 1,300 to 7,100 feet above sea level. Runoff in this stream, and in Pacoima Creek which drains an adjacent smaller mountain area, is partially regulated by flood control reservoirs, two on Tujunga and one on Pacoima. Both flow across highly absorptive alluvium, characterized by the coarse Tujunga soils which cover most of the easterly portion of the valley. Discharge to the river in Pacoima Creek has been somewhat reduced by spreading, and its summer flow is largely diverted at or above the canyon mouth. Several smaller streams, none of which are perennial in the valley, and most of which are dry throughout their length in all save storm periods, discharge their flood flows across the denser alluvium of the westerly half of the valley. Here accretions from precipitation on the valley are considerable.

Near the lower, southeasterly end of San Fernando Valley flood flow is augmented by discharge of Verdugo Creek, which originates in small streams on the north slope of Verdugo Mountains, and on the south slope of the San Gabriels two miles or more distant across La Crescenta Valley. The alluvium of this valley is highly absorptive, but its slope southward is steep and, for erosion control, several of the tributary channels have been paved. The main stream is paved through Verdugo Canyon and across San Fernando Valley to the river. It receives accretions of magnitude from the highly developed area bordering this reach. In the past, rising water originating in the ground water of La Crescenta Valley flowed through Verdugo Canyon. The greater part of this is now intercepted by wells of the City of Glendale, and a submerged dam near the lower end of the canyon.

Near the lower end of the Los Angeles Narrows, Arroyo Seco enters the river through low hills to the east. This stream drains about 24 square miles of the south slope of San Gabriel Mountains bordering the extreme northwest portion of San Gabriel Valley, and flows southward about two miles across absorptive alluvium at the southeast end of La Canada Valley into Devils Gate Reservoir. While the rate of absorption has been materially reduced by deposition of impervious material in the reservoir, percolation of water held there is still considerable. Below the dam the stream skirts the easterly toe of San Rafael Hills for a distance of about two miles. Prior to 1937 a part of the water released from the reservoir was absorbed in this reach, and drifted to the east into San Gabriel Valley. Since that time all but about 3,000 feet of the channel between the dam and Station 4035, at Colorado Street in Pasadena, has been paved, and virtually all of this percolation cut off. Rising water occurs at various points between Colorado Street and the river.

About 11 miles below the Narrows, Rio Hondo enters Los Angeles River from the east. In time of flood, in addition to a part of San Gabriel

River flow, Rio Hondo receives contributions from several streams which drain highly developed valley lands in the westerly portion of San Gabriel Valley, and tributary mountains and hills which bound it on the north and west. In the upper reaches of Rio Hondo, material underlying the channel is highly absorptive. For some distance upstream from Whittier Narrows, however, the water table is so high that ground water drains into the channel, and a perennial flow of rising water results. Below the Narrows, that part of the rising water which is not diverted for use is largely absorbed again by the alluvium, as is part of the flood water. Spreading grounds increase the amount of this percolation.

Of the tributaries to Rio Hondo, Eaton, Santa Anita and Sawpit Creeks drain considerable areas of mountain front land. Discharge of all three is to some extent regulated in reservoirs, and all flow for considerable distances across the alluvium in unpaved channels. Rubio and Alhambra drains, which handle storm waters from Pasadena and adjacent cities, are paved throughout.

About one mile upstream from Inglewood Fault, and six miles from the ocean, Compton Creek enters Los Angeles River from the west. It drains about 46 square miles of the westerly and southerly portions of Los Angeles, nearly all of it within the pressure area of the Coastal Plain. Thus, percolation from its tributary area is relatively small, and little of it reaches the strata from which water is pumped.

It is estimated that all streams which make up the Los Angeles River stream system discharge an average of about 130,000 acre-feet annually into the valleys from mountains and hills; that an annual average of approximately 400,000 acre-feet of precipitation falls on the valleys drained by the system, and that the discharge into the ocean averages between 60,000 and 70,000 acre-feet annually. Of this waste about 15,000 acre-feet originates in or above San Gabriel Valley and enters Los Angeles River through Rio Hondo.

San Gabriel River originates in about 214* square miles of the higher portions of the San Gabriel Mountains, flows southwesterly 14 miles across San Gabriel Valley to Whittier Narrows, then flows southward 20 miles to enter the ocean at Alamitos Bay east of Long Beach. Two flood control reservoirs in the mountains, and one overlying the alluvium near Azusa, particularly regulate the flow. There is considerable percolation in the stream-bed for about 10 miles below the mouth of the canyon, and this is increased by spreading. For a distance above the Narrows, varying from two to four and one-half miles with fluctuations of the ground water, rising water enters the channel. Below the Narrows for about eight miles the alluvium again absorbs a part of the flow. Spreading grounds have been constructed there, but at times a high water table has reduced their effectiveness. Across the pressure area, which extends northward from the ocean about 13 miles, percolation is negligible.

About four and one-half miles above the Narrows, Walnut Creek enters the river from the east. Big and Little Dalton and San Dimas Creeks join Walnut Creek a short distance above its mouth. All of these streams flow for 11 or more miles across absorptive alluvium, and all are affected by reservoir control, by direct diversions, or by spreading operations.

* A portion of this area contributes to Rio Hondo, which splits from San Gabriel River downstream from the mouth of San Gabriel Canyon, and thence flows to Los Angeles River.

San Jose Creek enters the river from the east just above Whittier Narrows. It originates at the easterly end of San Jose Hills near Pomona, and flows some 15 miles through San Jose Valley. At various points throughout the lower four miles of the valley small intermittent flows of rising water occur. For the last two miles above the junction with San Gabriel River this flow is continuous. Soils of the valley and its tributary hills are heavy, and the underlying alluvium is relatively dense. As a consequence, runoff is flashy and percolation rate relatively small.

Coyote Creek enters the river from the east about four miles upstream from the ocean. For a distance of about five miles bordering Puente Hills, in which it originates, its runoff flows into several streams across alluvium characterized by moderately permeable Yolo and Ramona soils. For the remainder of its length the stream flows across the pressure area. Here the channel serves to drain off a part of the water held near the ground surface by underlying clay strata. A small part of flood flow is partially regulated in a small flood control reservoir on Brea Creek.

It is estimated that San Gabriel River and its tributaries discharge an average of about 70,000* acre-feet annually into the valley from mountains and hills; that an annual average of approximately 200,000 acre-feet of precipitation falls on valleys drained by the system; and that annual discharge into the ocean average about 20,000 acre-feet. An additional 15,000 acre-feet originating in or above San Gabriel Valley reaches the ocean in Los Angeles River.

Santa Ana River originates in about 173 square miles of high mountains at the easterly end of the San Bernardino range, flows southwesterly across Upper Santa Ana Valley 40 miles to Prado, thence in about the same direction 12 miles through Santa Ana Narrows, thence more southerly 19 miles across the Coastal Plain to the ocean just west of Newport Bay. For approximately 10 miles after leaving the mountains the stream flows across absorptive alluvium, where percolation is augmented by spreading. Below this reach, near San Bernardino, the water table is high, and at times water rises in the stream. Between Colton and Riverside the stream is generally dry in the summer, partly because of diversions, and partly due to percolation, but between Riverside and the headworks of Santa Ana Valley Irrigation Company and Anaheim Union Water Company canals, the Santa Ana Narrows several miles below the county line, there is continuous flow of rising water. Approximately half way between the Narrows and the ocean the stream enters the pressure area of the Coastal Plain. Above this point the alluvium is absorptive, and percolation occurs both naturally and from spreading. In the pressure area percolation is negligible. Operation of Bear Valley Reservoir in the mountains, where water is stored for later release and diversion from the stream, reduces flow in the river at the canyon mouth and at all points below. Prado Reservoir, at the upper end of the Narrows, operated for flood control, materially reduces peak discharges across the Coastal Plain, but its effect on total waste to the ocean is relatively small.

Between the mountains and the area of rising water near San Bernardino, several tributaries, the largest of which are Mill Creek from the south and Plunge Creek from the north, enter the river. Together these

* An additional 60,000 acre-feet, including half the inflow tributary to San Gabriel River above Rio Hondo and all inflow to western San Gabriel Valley tributary to Rio Hondo, contributes to the water supply of San Gabriel Valley, but is herein considered to be a part of Los Angeles River stream system.

drain a considerable area of the south slope of San Bernardino Mountains. These streams flow for some distance across porous alluvium, and percolation is increased by spreading on the larger streams.

Just east of Colton, Warm Creek enters the river from the north. Many streams originating in the mountains between City Creek and Lytle Creek contribute to the storm flow of War Creek. These flow for long distances across porous alluvium, and spreading is resorted to on virtually all of them. High flood flows of City Creek are diverted southward into the lower reaches of Plunge Creek, and at times in the past a portion of Lytle Creek discharge followed the west channel through the City of Colton, and entered the river downstream from the mouth of Warm Creek. A recently constructed concrete lined channel, designed to carry virtually all flow of Lytle Creek, extends from Foothill Boulevard to Warm Creek. In its lower reaches Warm Creek flows through a zone of rising water, and there is at all times a considerable flow of water available for diversion, or for percolation in the stream-bed near and below Colton.

In or near this area of rising water, and a short distance upstream from the mouth of Warm Creek, San Timoteo Creek enters the river from the south. Its length, between the comparatively small area of tributary mountain front, north of Beaumont and Yucaipa, and the river, is about 24 miles. Near the mountains the alluvium is porous, and flow in the creek is small. Below this percolating area for a distance of 13 miles the stream flows in a narrow canyon incised into older folded alluvium. At various points in this reach some rising water comes to the surface. After leaving this canyon the stream flows for about five miles across the recent alluvium of the valley, where channel improvement holds it to a narrow bed, but where there is some percolation.

Between Lytle Creek and the western extremity of Upper Santa Ana Valley several streams flow into the valley from the mountains to the north. Of these, San Antonio Creek is the largest. It enters the river just above the Narrows by way of Chino Creek. Because of natural percolation in its long channel across the alluvium, and of operation of extensive spreading grounds on its upper reaches, discharge to the river is small in relation to mountain run-off. The same is true of Cucamonga Creek and smaller streams.

Temescal Creek, which drains a portion of the north slope of Santa Ana Mountains, and the hill area south of Arlington, and only very rarely carries a small outflow from Lake Elsinore, enters the river from the south a short distance upstream from the mouth of Chino Creek. There is some percolation throughout the 27 miles between the lake and river.

On the Coastal Plain, about 10 miles upstream from the ocean, near the upper boundary of the pressure area, Santiago Creek enters the river from the east. This stream drains about 57 square miles of the south slope of Santa Ana Mountains. Santiago Reservoir, to which a large part of the drainage area is tributary, is operated for conservation, and a considerable part of the discharge of the stream is stored and diverted for use. Percolation into the alluvium in the 12-mile reach between the mountains and river further decreases the discharge.

It is estimated that Santa Ana River and its tributaries discharge an average of about 240,000 acre-feet annually into the valleys from mountains and hills; that an annual average of approximately 630,000 acre-feet of precipitation falls on valleys drained by the system; and that annual average discharge into the ocean is about 21,000 acre-feet.

GROUND WATER BASINS

The geology of the area is discussed in detail in an earlier bulletin published by the Division of Water Resources as a part of South Coastal Basin Investigation.* There it is shown that the basement complex and older sedimentary rocks, of which the mountains and hills are the surface expression, are in general so dense that extraction of ground water from them is not practical, and movement of water through them is insignificant. The more porous valley fill which overlies this bed-rock is, however, the immediate source of a large water supply.

In that bulletin, the four large valley areas are subdivided into ground water basins, largely on the basis of variations in the behavior of the ground water. They are listed below, and the location of each is shown on Plate 1. These basins constitute several series of underground reservoirs in which water goes alternately into and out of storage.

San Fernando Valley
- 1. San Fernando
- 2. Sylmar
- 3. Tujunga
- 4. Pacoima
- 5. Verdugo
- 38.[a] Bull Canyon
- 39.[a] Little Tujunga

San Gabriel Valley
- 6. Main San Gabriel
- 7. Monk Hill
- 8. Raymond
  - 8a. Pasadena Area
  - 8b. Santa Anita Area
- 9. Upper Canyon
- 10. Lower Canyon
- 11. Glendora
- 12. Way Hill
- 13. San Dimas
- 14. Foothill
- 15. Puente

Upper Santa Ana Valley
- 16. Chino
- 17. Claremont Heights
- 18. Live Oak
- 19. Pomona
- 20. Cucamonga
- 21. Rialto-Colton
  - 21a. Rialto
  - 21b. Colton
- 22. Bunker Hill
- 23. Lytle
- 24. Devil Canyon
- 25. Yucaipa-Beaumont
  - 25a. Yucaipa
  - 25b. Beaumont
- 26. San Timoteo
  - 26a. North Area
  - 26b. South Area
- 27. Riverside
- 28. Arlington
- 29. Temescal
- 30. Spadra
- 40.[a] Lower Cajon
- 41.[a] Upper Cajon
- 42.[a] Bear Valley
- 43.[a] Big Meadows
- 44.[a] Seven Oaks
- 45.[a] Reche Canyon
- 46.[a] Cajalco
- 47.[a] Lee Lake
- 48.[a] Cold Water
- 49.[a] Bedford

Coastal Plain
- 31. West Coastal Plain
  - 31a. Northern Area
  - 31b. Southern Area
- 32. Hollywood
- 33.[b] Central and East Coastal Plain
  - 33a. Los Angeles Area
  - 33b. Montebello Area
  - 33c. Santa Ana Area
  - 33d. Irvine Area
  - 33e. Central Coastal Plain Pressure Area
  - 33f. East Coastal Plain Pressure Area
- 34. La Habra
- 35. Yorba Linda
- 36. Los Angeles Narrows
- 37. Santa Ana Narrows
- 50.[a] Santiago

[a] Listed as "Miscellaneous" in Bulletin 45.

[b] For convenience of study and discussion, areas designated in Bulletin 45 are further subdivided. Los Angeles and Montebello Areas serve as forebays for Central Costal Plain Pressure Area, and Santa Ana Area as a forebay for East Coastal Plain Pressure Area. In effect, each group constitutes a single basin. To a lesser degree, Irvine Area is also a forebay for East Coastal Plain Pressure Area, but it is treated later herein as a separate basin.

* Bulletin No. 45, South Coastal Basin Investigation, "Geology and Ground Water Storage Capacity of Valley Fill," 1934.

Characteristics of fill material within the basins vary widely, both areally and throughout the section from bed-rock to ground surface. All of the gravels have at some time been at or near the surface, and the same phenomena which produced the materials now visible have been active throughout the period of deposition. Since their beginning, streams have carried debris from the mountains and dropped it in the valleys, the larger and heavier gravels near canyon mouths, and the finer materials nearer the periphery of the cone of deposition. Large floods, occurring periodically, carry heavy materials farther and drop them upon finer gravels deposited by smaller flows. At various times during the ages, moreover, just as in recent times, a part of the streams have, for a portion of their length, cut so far beneath the general surface that materials outside their channels lay exposed to weathering for long periods of time, and the gravels, to varying depths, have been partially or wholly changed to clay. Following each such period of weathering, fresh gravels have again been deposited on the surface, and alternating strata of gravels and clay result. The weathered areas are often irregular in outline, and in such case the clay occurs as lenticular masses scattered throughout the more open alluvium. From time to time, portions of the area have been covered by water. Where this has occurred, very fine material has been deposited over considerable areas, forming an almost continuous horizontal barrier between gravels above and below it. Elsewhere, periodic swamp conditions have brought about the formation of layers of dense black clay, originally and in some cases still high in organic matter.

Recurrent movements within the earth's crust since the beginning of Quaternary time have been in part responsible for the periodic changes in the character and courses of the depositing streams which have caused the variations just described. They have also been directly responsible for significant changes in the position of the material since its deposition and alteration by weathering. In certain areas the strata have been folded; elsewhere faults cut through the alluvium and have either formed more or less continuous dikes of fine fault gouge materials, or have offset pervious strata against impervious. In neither case is it likely that the impervious barrier is complete, but in either, the pervious cross section at the fault is doubtless less than on either side.

Boundaries of the basins as herein delimited are generally faults, hills or relatively impervious zones. In all cases but those of continuous hills some restricted underflow across the boundaries is possible. In some instances ground water divides, or depressions in the water table which mark a sharp difference in the direction of flow on either side, constitute the boundary. The location of such divides may vary from time to time in which case the direction of underflow across the chosen boundary may also vary. Elsewhere, where no barrier of any kind exists, arbitrary lines are drawn in order to completely bound the area designated as a ground water basin. Within basins, the considerable variation in character of the material affects the behavior of the ground water, and further subdivision might be logical. Convenience for study is the basis for the division as made, and whether or not any legal significance attaches depends entirely upon behavior of the ground water, rather than upon the designation herein of a particular area as a separate ground water basin.

CHAPTER III. WATER SUPPLY OF SOUTH COASTAL BASIN

With the exception of an annual import of a little more than a quarter of a million acre-feet, principally by the City of Los Angeles and Metropolitan Water District, all of the water supply for approximately 500 square miles of municipal development, and 760 square miles of irrigated agricultural lands within South Coastal Basin is from local sources. Of this, roughly three-fourths is obtained by pumping from ground water, the rest by diversion from surface streams.

There are three types of surface diversion: (1) from mountain canyons with no upstream regulation; (2) from mountain streams regulated to a varying degree in upstream flood control or conservation reservoirs; and (3) from rising water naturally regulated in the ground water basins above. The ratio between amount diverted and mean flow of the stream increases generally in the order named, but in no case does it approach unity.

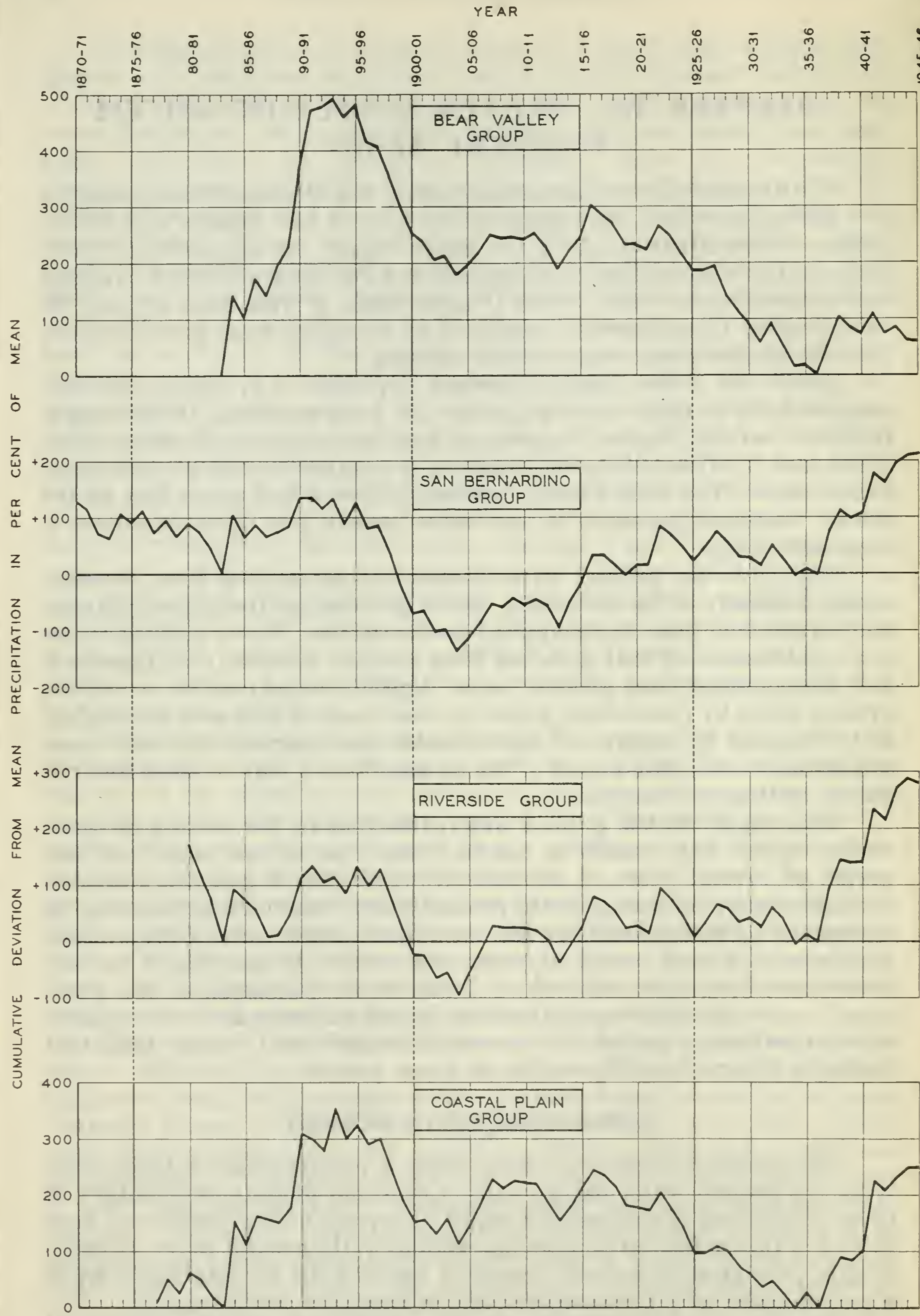
Supply to the ground water consists of percolation from streams, either naturally or by spreading, direct percolation from precipitation, and return flow from water applied on the surface. Water applied to use is a combination of that diverted from surface streams, that imported, and that pumped from ground water. Applied water may return to the ground water by percolation below the root zones of irrigated vegetation, or by disposal of sewage and other wastes into cesspools. In some cases sewage may constitute a part of the stream flow, it may be used for irrigation or it may be spread.

This supply to the ground water, like that in the surface streams, varies widely from month to month, from year to year and from one period of several years to another. However, the regulation provided through changes in storage in the ground water reservoirs, when pumping is resorted to, makes available for use a much larger part of the average supply over a long period of years than would be possible if surface diversions alone were resorted to. Thus, in an evaluation of the water supply where ground water is utilized, it is the average amount available over an unlimited period of time which is significant, rather than that during a shorter, possibly wetter or dryer period.

LONG-TIME MEAN PERIOD

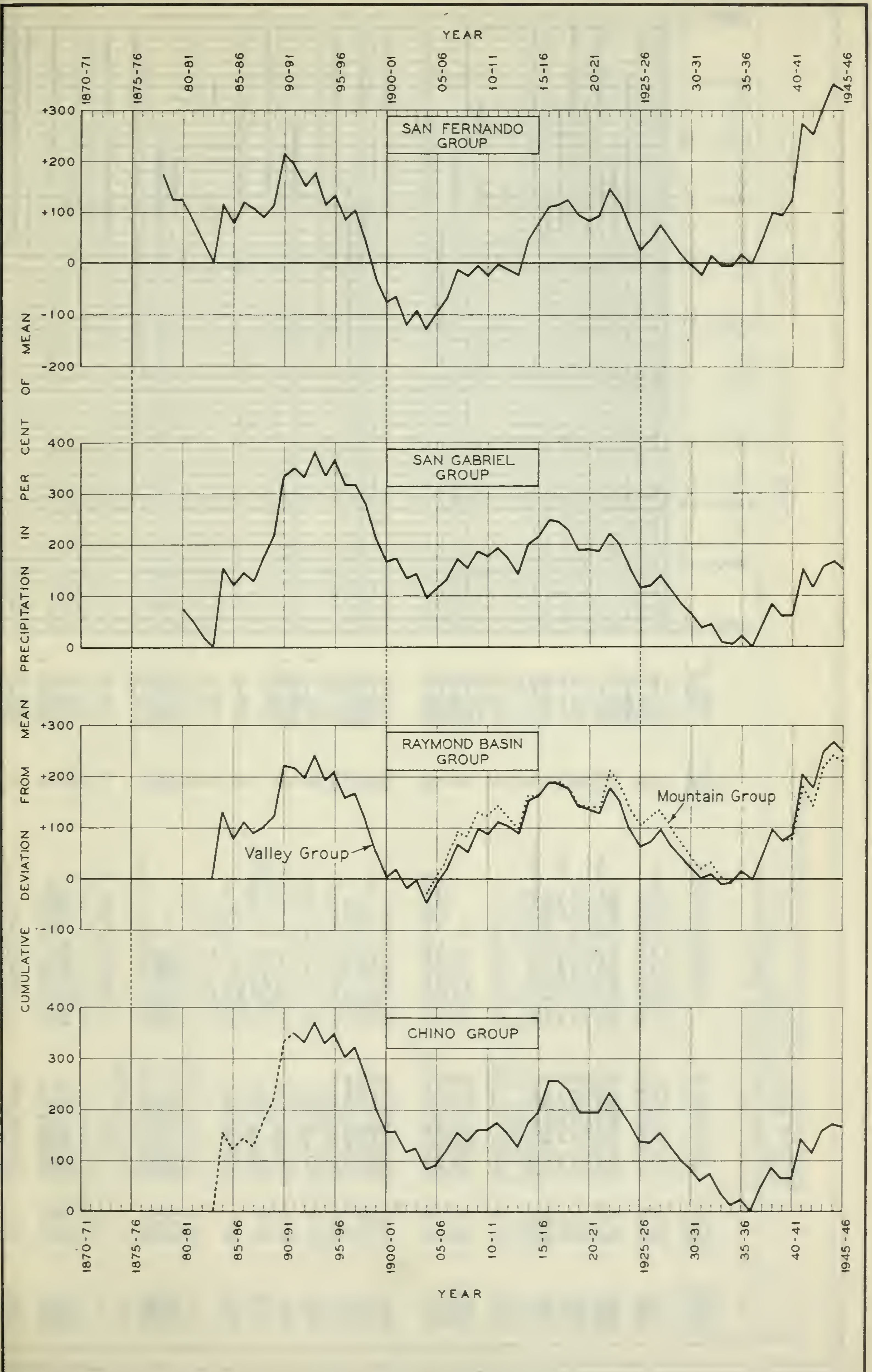
The primary source of all local water is precipitation on lands overlying the ground water basins, and on hills and mountains tributary to them. Variations in this amount result in corresponding variations, both in flow of the surface streams and accretions to the ground water. Because of this, precipitation records provide a logical basis for establishment of a period which is to be considered one of long-time mean supply.

Records of precipitation extending back over varying periods of time are available for about 900 stations in South Coastal Basin. At each it varies widely from month to month, from year to year, and from one period of several years to another. Because of this, recorded precipita-

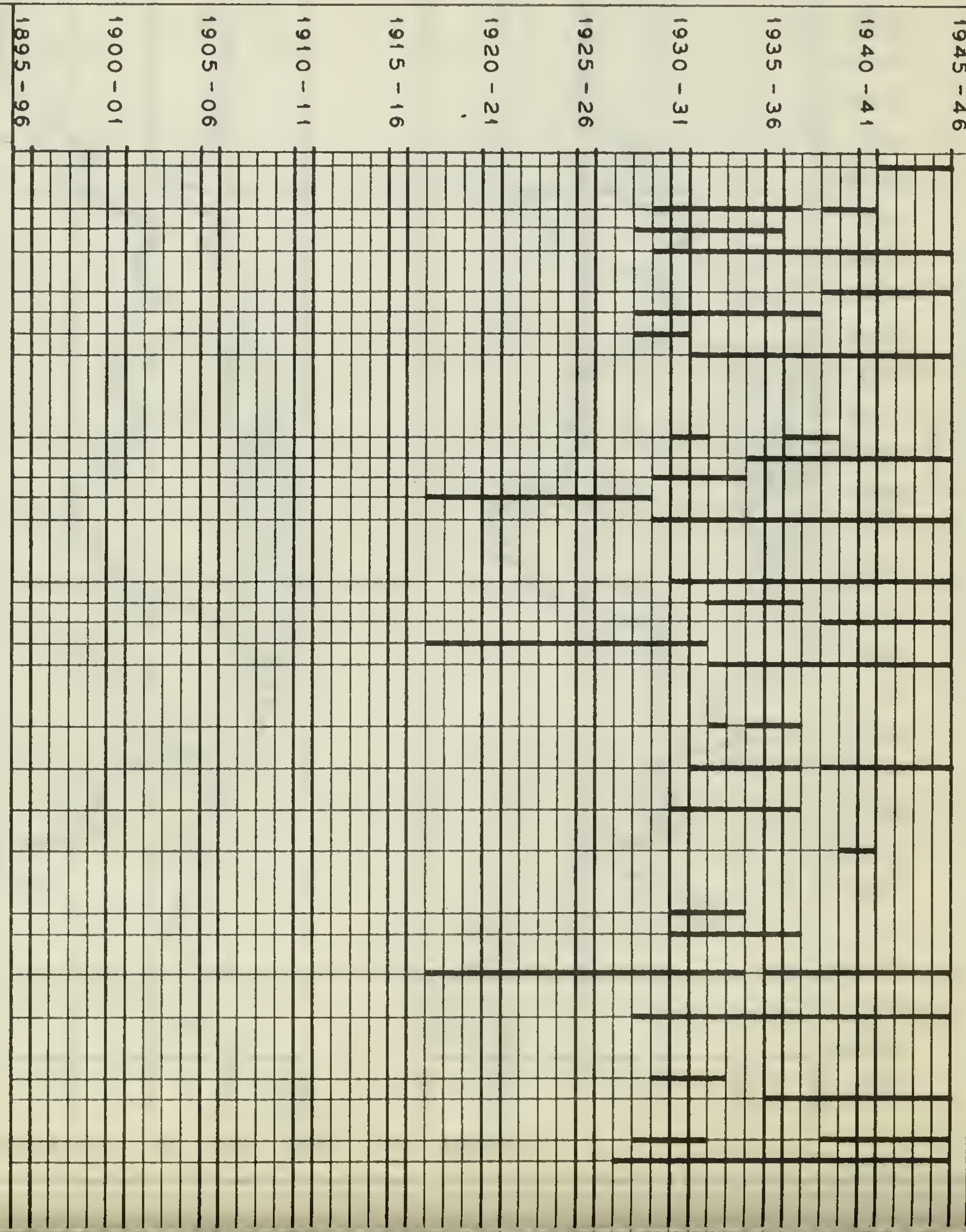


CUMULATIVE DEVIATION
FROM 53 YEAR MEAN PRECIPITATION

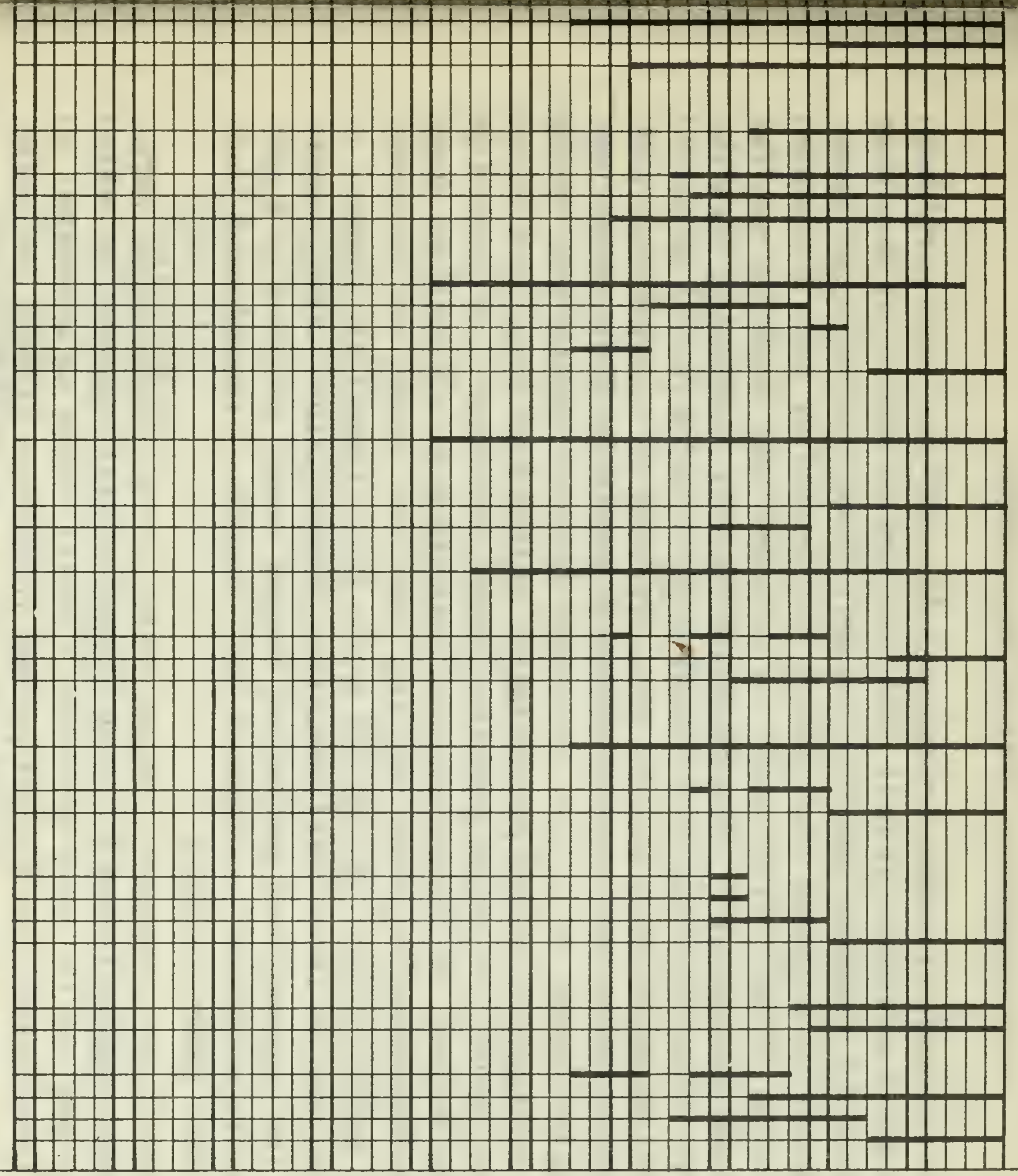
MEAN PERIOD: JULY 1, 1883 TO JUNE 30, 1936


YEAR
1870-71
1875-76
80-81
85-86
90-91
95-96
1900-01
05-06
10-11
15-16
20-21
1925-26
30-31
35-36
40-41
1945-46
SAN FERNANDO GROUP
SAN GABRIEL GROUP
RAYMOND BASIN GROUP
Mountain Group
Valley Group
CHINO GROUP
CUMULATIVE DEVIATION FROM MEAN PRECIPITATION IN PER CENT OF MEAN
+300
+200
+100
0
-100
-200
400
300
200
100
0
+300
+200
+100
0
-100
400
300
200
100
0
YEAR

STATION NUMBER	MAP INDEX	STREAM SYSTEM	RECORDING STATION	MEAS. BY	YEARS OF RECORD
3733	F- 5	Los Angeles R.	Below Sepulveda Blvd.	B	1941-45
3754	F- 5	Los Angeles R.	At Van Nuys Blvd.	B	1929-37 & 1938-41
3835	F- 7	Los Angeles R.	At Vineland Avenue	B	1928-36
2771	G-10	Los Angeles R.	At Dayton Ave. Bridge	A-B	1929-45
1524	J-11	Los Angeles R.	At Firestone Blvd.	B	1938-45
1525	K-11	Los Angeles R.	At Stewart & Gray Rds.	A-B	1928-38
899	N-10	Los Angeles R.	At Willow Street	B	1928-31
390	N-10	Los Angeles R.	At State St.-Long Beach	A	1931-45
4704	C- 3	Brown's Canyon	At Devonshire	B	1930-32 & 1936-39
6006A	B- 6	Pacoima Creek	At Dam	B	1934-45
6006B	B- 6	Pacoima Creek	Below Dam	B	1929-34
6006	B- 6	Pacoima Creek	1000' below 6006B	A	1917-29
4847	D- 5	Pacoima Creek	At Parthenia Street	B	1929-45
6249	B-11	Tujunga Creek	At Edison Rd.	A-B	1930-45
5100	C-10	Tujunga Creek	Below Dam	B	1932-37
5101	C-10	Tujunga Creek	1600' below Dam	B	1938-45
6139	B- 9	Tujunga Creek	1000' above 6129	A-B	1917-32
6129	B- 9	Tujunga Creek	Above Gold Canyon	A-B	1932-45
4913	C- 7	Tujunga Wash	At Stonehurst Avenue	B	1932-33 & 1934-37
3783	F- 6	Tujunga Wash	W. Channel at Magnolia Blvd.	B	1931-37 & 1938-45
3813	F- 7	Tujunga Wash	E. Channel at Magnolia Blvd.	B	1930-37
3813A	E- 7	Tujunga Wash	Central Channel at Chandler Blvd.	B	1939-41
6268	B-11	Mill Creek	Near Mouth	A-B	1930-34
6229	B-11	Fox Creek	Near Mouth	A-B	1930-37
5023	C- 9	Haines Canyon	Near Tujunga	A-B	1917-34 & 1935-45
4922	C- 7	Little Tujunga Canyon	At Foothill Blvd.	A-B	1928-45
3953	F- 9	Verdugo Wash	At Glenoaks Blvd.	B	1929-33
3924	F- 9	Verdugo Wash	At Estella Avenue	B	1935-45
3974	F-10	Sycamore Can.	At Solway Street	B	1928-32 & 1938-45
3956	F- 9	Sycamore Can.	At Adams Square	B	1927-45
5127	D-11	Arroyo Seco	Near Pasadena	A	1913-15 &



4010	E-11	Flint Wash	At Berkshire Avenue	D	1923-45
4021A	E-11	W. Altadena Dr.	At Arroyo Seco	D	1936-45
4034	F-11	Seco Drain	Near Rosemond Avenue	D	1926-45
2960	G-13	Rio Hondo	At Lower Azusa Road	B	1932-45
2926	I-13	Rio Hondo	1000' above Mission Bridge	A-B-E	1928-45
2937	I-13	Rio Hondo Sl.	At San Gabriel Blvd.	B-E	1929-45
1535	K-11	Rio Hondo	At Stewart & Gray Rd.	A-E	1925-45
4180	E-14	Santa Anita Can.	Above Santa Anita Dam	A	1916-43
4181B	E-14	Santa Anita Cr.	Below Dam	B	1927-35
4181C	E-14	Santa Anita Cr.	400' below Dam	B	1935-37
4174	F-13	Big Santa Anita	At Foothill Blvd.	E	1923-27
4174B	F-13	Big Santa Anita	At Foothill Blvd.	B	1938-45
4151A	E-13	Little Santa Anita	Near Sierra Madre	A	1916-45
4152A	E-13	Little Santa Anita	270' below Sierra Madre Dam	B	1936-45
4152	E-13	Little Santa Anita	1/4 mile below Dam	B	1930-35
4090	E-12	Eaton Canyon	Near Pasadena	A	1918-45
4117	F-12	Eaton Wash	At Huntington Drive	D-E	1925-26, 1929-31 & 1933-36
4116	F-12	Eaton Wash	At San Pasqual Street	D-E	1939-45
2941A	G-13	Eaton Wash	At Sunset Avenue	B	1931-41
4108	G-12	Upper Rubio Wash	At Rose Avenue	D-E	1923-45
2910	G-12	Rubio Wash	At Broadway	B	1929-30 & 1932-36
2922	H-13	Rubio Wash	At Glendon Way	B	1936-45
2880A	G-12	W.Alhambra Wash	At So. Pacific R.R.	B	1930-32
2880B	G-12	E.Alhambra Wash	At So. Pacific R.R.	B	1930-32
2903	H-12	Alhambra Wash	At Garvey Avenue	B	1930-36
2914	H-12	Alhambra Wash	Near Short Street	B	1936-45
4057	G-11	Broadway Drain	At Raymond Fault	D-E	1934-45
4057A	G-11	Granada Drain	At Raymond Fault	D-E	1935-45
4068	G-12	Broadway Drain	At Mission Street	D-E	1923-27 & 1929-34
2899	I-12	Montebello Dr.	At Montebello	B	1932-45
1459	L- 9	Compton Creek	At Rosecrans Blvd.	B	1928-38
881	L-10	Compton Creek	At Greenleaf Drive	B	1938-45



LEGEND:

A Measurements by United States Geological Survey.
B " " Los Angeles County Flood Control District.
C " " Orange County Flood Control District.
D " " Pasadena Water Department.
E " " State Division of Water Resources and Predecessors.

PERIODS OF STREAM FLOW RECORDS

LOS ANGELES RIVER SYSTEM

tion at any two stations is directly comparable only for those periods in which a record is available at both. The average of record, at any save the longest record stations, may vary widely from the long-time mean. However, it has been found that during the period of record common to all, variation from year to year on a percentage basis is not far different at all stations in the same general vicinity. Assuming that the same was true in earlier years, precipitation prior to the period of record at any short record station can be reconstructed by comparison with that at a station where the complete record is available. This comparison is facilitated by the use of indices, the index for a particular year being the percent relationship which precipitation in that year bears to average precipitation during the entire period of years for which it is desired to complete the record. If the regimen of variation at all stations were identical, indices at all stations for any one year would be the same. It is found, however, that this is not quite true. Therefore, instead of comparing all shorter record stations with a single station having record throughout the chosen mean period, all longer record stations in a particular area are arranged in order of their length of record, and their indices for each year averaged.

On Plate 2 are presented graphs which show accumulated variation from mean precipitation for nine groups of stations, each of which represents a part of the area of South Coastal Basin as delimited on Plate 1. On these graphs the 53-year period, 1883-84 to 1935-36, inclusive, is assigned the mean index 100. During the period of longest record prior to 1883-84 the average index was less than 100; from 1884-85 to 1892-93 it was greater; from 1893-94 to 1903-04 it was again less; from 1904-05 to 1915-16 it was again greater; from 1916-17 to 1935-36 it was again less; and since 1936-37 it has again been greater than 100. While the variation is not cyclic in a mathematical sense, in that the two pairs of wet and dry periods are not identical, each pair for want of a more descriptive word is termed a cycle. While the mean for the entire record is not far different from that for the two complete cycles, 1883-84 to 1935-36, it is more logical to consider the latter a period which is representative of long-time mean conditions, and to assign to it the index 100, because neither the falling period which preceded it, nor the rising period which followed is known to be complete.

As previously stated, not all percolation to the ground water is directly from rainfall. A considerable part is from surface stream-flow. To evaluate total long-time mean supply, an estimate of long-time mean discharge at points where the stream enters and leaves the basin is required. No stream-flow records are available prior to 1894, and while it is true that a relationship between precipitation and runoff exists, it is not sufficiently definite to provide the basis for a reliable estimate of the 53-year mean flow, even at the few stations of longest runoff record. For this reason, shorter periods in which some stream-flow records are available are used as a basis for estimating long-time mean supply from that source.

Average annual runoff, during any period which constitutes a complete or nearly complete precipitation cycle, and during which average annual precipitation is not far from its long-time mean, should not be far different from long-time mean annual runoff. One such period, 32 years in length, starts with 1904-05 and ends with 1935-36. Because of the fact that percolation to the ground water along San Gabriel River was considerably altered in 1933-34, through operation of reservoirs and increased diversions and spreading, the mean annual precipitation on the area tributary to that stream and to Los Angeles River was about the same during the 29-year period ending with 1932-33 as in the 32-year year period, the 29-year period might better be used for those two stream systems. The 21-year period, 1922-23 to 1942-43, inclusive, while possibly not a complete cycle may also be used. In Table 4 is shown the percentage by which average annual precipitation in each of these periods varies from the 53-year mean.

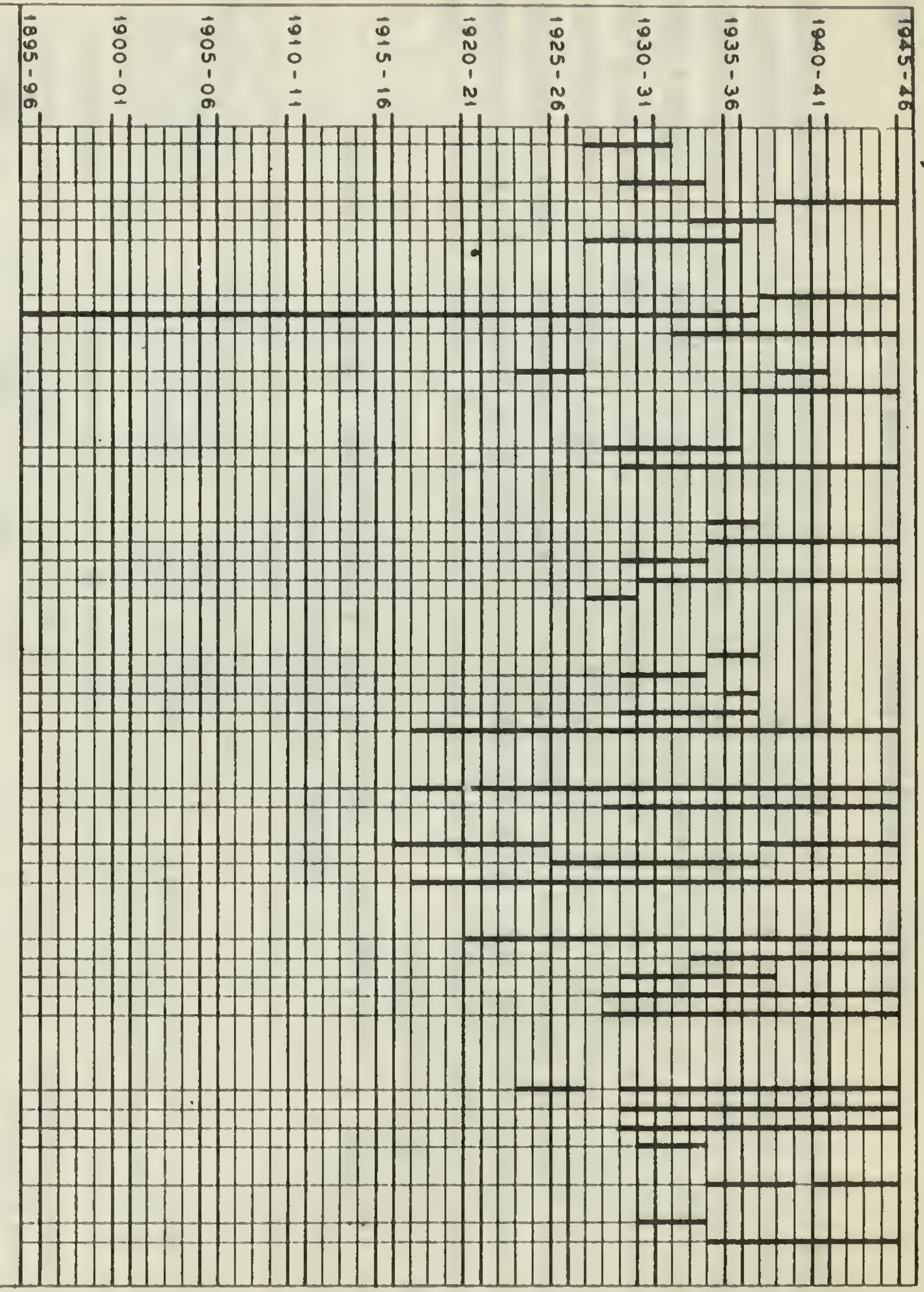
TABLE 4. AVERAGE ANNUAL VARIATION FROM 53-YEAR MEAN PRECIPITATION

Precipitation station group	*32-year period 1904-05 to 1935-36, incl.*	*29-year period 1904-05 to 1932-33, incl.*	*21-year period 1922-23 to 1942-43, incl.*
	(Percent)	(Percent)	(Percent)
San Fernando	+4.1	+4.4	+7.6
San Gabriel	—3.0	—3.0	—3.0
Raymond Basin:			
Valley	--	+1.3	+3.4
Mountains	--	+1.3	+0.4
Chino	—2.6	—1.5	—3.6
Bear Valley	—5.6	--	—8.8
San Bernardino	+4.2	--	+5.1
Riverside	+3.0	--	+8.2
Coastal Plain	—3.6	—3.1	+1.2

As indicated on Plates 3, 4, 5 and 6, records of discharge at one point on each of a few streams extend throughout the 32-year or 29-year cycles. By comparison with these records, estimates of flow during the cycle at other points on these streams, and in other streams where records are available during a part of the cycle, can be made. While the relationship between discharges of streams in the same general vicinity is better than that between precipitation and runoff, these estimates are also subject to error. In estimates of discharge at points far downstream, based on records at points higher up, errors may be large. Reference to Plates 3, 4, 5 and 6 shows that during the 21-year period points at which the discharge must be estimated are greatly reduced in number, and at some points where estimates are required a record is available for the greater part of the period. Locations of stream gaging stations are shown on Plate 7.

Results obtained by using one period or the other may in some cases differ materially. The weight to be given to each depends upon the circumstances, and is of necessity a matter of judgment. In Table 4 it is shown that precipitation over the greater part of the area during the 21-year period averaged higher than that during either the cycle starting with 1904-05, or during the 53-year mean period. On the other hand, values presented later in the bulletin show that average annual stream-flow is less in the later cycle. Generally speaking, values of overdraft or excess resulting from use of the 21-year period are the more conservative, and except where noted, the values presented in Table 5 in Chapter IV are based on that period. Values based on the 29- or 32-year cycles are, however, stated in Chapter VI for purposes of comparison.

STATION NUMBER	MAP INDEX	STREAM SYSTEM	RECORDING STATION	MEAS. BY	YEARS OF RECORD
5536	D-18	E.Fk.San Gabriel	Camp Bonita, above Cattle Canyon	A-B	1927-32
5526	D-18	E.Fk.San Gabriel	Below Cattle Canyon	B	1929-34
5496	D-18	E.Fk.San Gabriel	2½ miles above Fork	B	1938-45
5486	D-18	E.Fk.San Gabriel	2 miles above Fork	B	1933-38
5448B	E-17	San Gabriel	At Edison Intake	B	1927-36
4313	F-16	San Gabriel	Near Azusa	B	1937-45
4294	F-16	San Gabriel	Near Azusa	A	1895-1937
4256	F-15	San Gabriel	At Foothill Blvd.	B	1932-45
2985	H-14	San Gabriel	At Elliott Avenue	B-E	1923-27 & 1938-41
2939	I-13	San Gabriel	At Beverly Blvd.	B	1936-45
1620	I-13	San Gabriel	At Whittier Blvd.	A-B	1928-36
1008	N-12	San Gabriel	At Spring Street	B	1929-45
5285	D-14	W.Fk.San Gabriel	3½ miles above Dam #2	B	1934-37
5345	D-15	W.Fk.San Gabriel	Below Dam #2	B	1934-45
5385	D-16	W.Fk.San Gabriel	Above North Fork	B	1929-34
5435	D-17	W.Fk.San Gabriel	At Camp Rincon	A-B	1930-45
5445	D-17	W.Fk.San Gabriel	1/2 mile above East Fork	B	1927-30
5324	D-15	Devil Creek	1 mi.above W.Fk.San Gab.	B	1934-37
5414	D-16	Bear Creek	Near Camp Rincon	A-B	1929-34
5415	D-16	Bear Creek	500' above W.Fk.San Gab.	B	1935-37
5444	D-17	N.Fk.San Gabriel	Near Mouth	A-B	1929-37
4293	F-16	Rogers Creek	Near Azusa	A-B	1917-45
4273	F-15	Fish Creek	Near Duarte	A-B	1917-45
4212A	E-14	Monrovia Creek	Near Mouth	B	1928-45
4212	E-14	Sawpit Creek	300' below Monrovia Cr.	A	1916-25 & 1937-45
4202	E-14	Sawpit Creek	1050' below Monrovia Cr.	A	1925-37
4425	F-18	San Dimas Creek	Near San Dimas	A	1917-45
4374	F-17	Big Dalton Can.	Near Glendora	A	1920-45
4363	F-17	Little Dalton	Near Mouth of Canyon	B	1938-45
4364	F-17	Little Dalton	Near Mouth of Canyon	B	1929-38
4457	G-19	Live Oak Creek	Near Mouth of Canyon	B	1928-45
3180	G-18	Puddingstone Cr.	Below Dam	B	1928-45
3013	H-14	Walnut Creek	At Covina Boulevard	B-E	1923-27 & 1929-45
2967	I-13	San Jose Creek	At Workman Mill Road	B	1929-45
1045	M-13	Coyote Creek	At P.E. Ry. & Anaheim St.	B	1929-45
1171	L-15	Brea Creek	At Fullerton	C	1930-34
1172	L-15	Brea Creek	Near Malden Avenue	C	1934-39 & 1940-45
15511	L-16	East Fullerton Cr.	At Cypress Avenue	C	1930-34
1192	L-16	East Fullerton Creek	At Raymond Avenue	C	1934-45

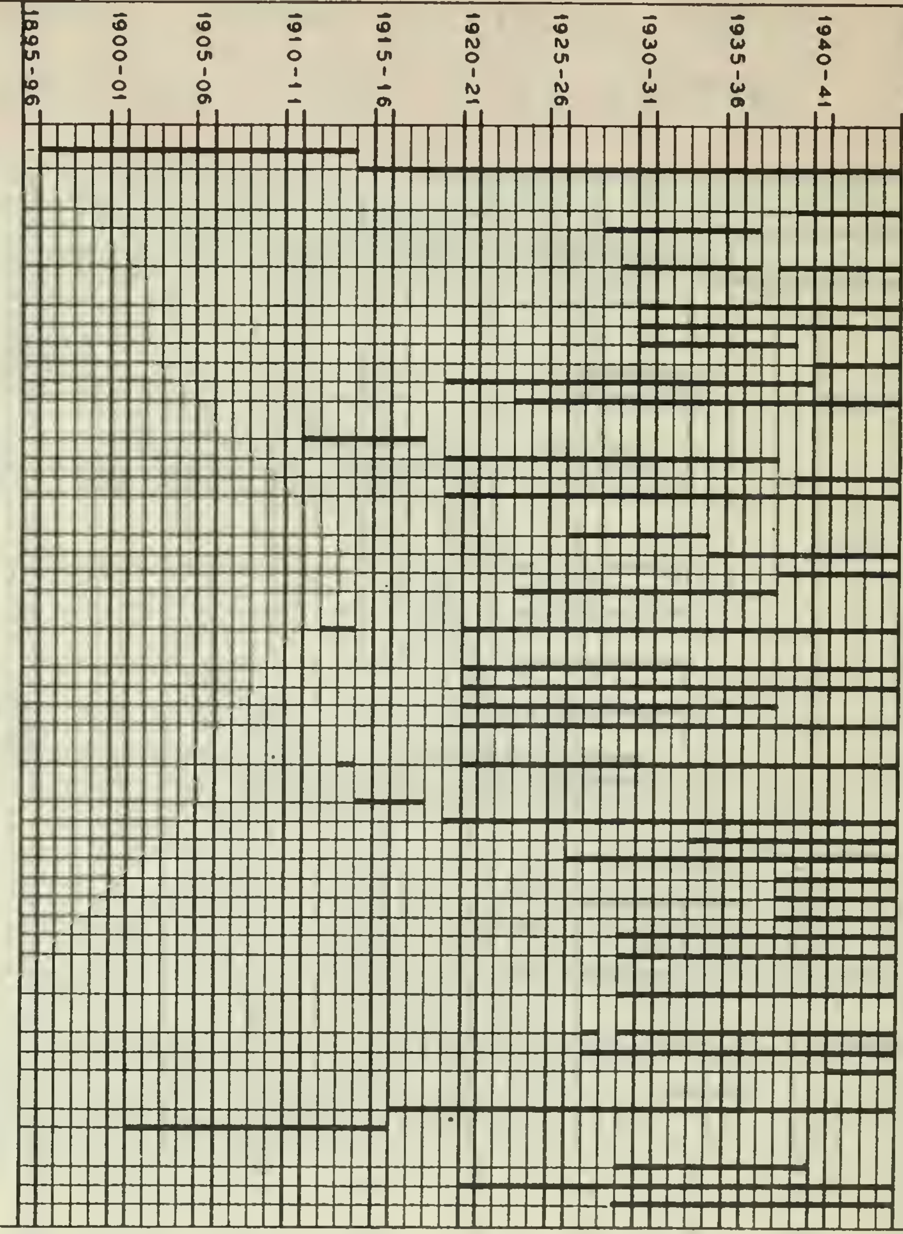


LEGEND

A Measurements by United States Geological Survey.
B " " Los Angeles County Flood Control District.
C " " Orange County Flood Control District.
D " " Pasadena Water Department.
E " " State Division of Water Resources and predecessors.

PERIODS OF STREAM FLOW RECORDS
SAN GABRIEL RIVER SYSTEM

STATION NUMBER	MAP INDEX	STREAM SYSTEM	RECORDING STATION	MEAS. BY	YEARS OF RECORD
19017	G-32	Santa Ana	Warm Springs Canyon Ford	A	1896-1914
19008	G-31	Santa Ana	Near Mentone	A	1914-45
18003	H-28	Santa Ana	"E" Street Bridge - San Bernardino	A	1939-45
18041	H-28	Santa Ana	Near San Bernardino	A	1928-37
16953	J-25	Santa Ana	Riverside Narrows	A	1929-37 & 1938-45
16835	K-22	Santa Ana *	Hamner Avenue	A	1930-45
16807	K-22	Santa Ana *	Auburndale Bridge	A	1930-45
15851	L-21	Santa Ana *	Near Prado	A	1930-39
15851A	L-21	Santa Ana	Near Prado below Prado Dam	A	1940-45
15822	L-20	Santa Ana	At Prado	A	1919-40
14495	O-16	Santa Ana	At Santa Ana	A	1923-45
18360	G-34	Mill Creek	Forest Home	A	1911-18
18261	G-32	Mill Creek	Near Craftonville	A	1919-38
18181	G-31	Mill Creek	Near Mentone	A	1939-45
18957	G-30	Plunge Creek	Near East Highland	A	1919-45
18128	I-30	San Timoteo Cr.	Near Redlands	A-E	1926-34
18096	I-29	San Timoteo Cr.	Near Redlands	A	1934-45
18915A	F-30	City Creek	Near Highland	A	1938-45
18915	F-30	City Creek	Near Highland	A	1923-38
18820	E-28	Waterman Canyon	Near Arrowhead Springs	A	1912-14 & 1920-45
18832	E-28	Strawberry Cr.	Near Arrowhead Springs	A	1920-45
17993A	H-27	Warm Creek	Near Colton	A	1920-45
19433A	C-24	Lone Pine Creek	Near Keenbrook	A	1920-38
19433B	C-24	Cajon Creek	Near Keenbrook	A	1920-45
19569	E-27	Devil Canyon	Near San Bernardino	A	1913-14 & 1920-45
19416	D-24	Lytle Creek	Near San Bernardino	A	1914-18
19449	E-25	Lytle Creek	Near Fontana (Mouth of Canyon)	A-F	1918-45
18703	F-26	Lytle Creek	At Junction with Cajon Creek	F	1938-45
18704	F-26	Lytle Creek	Fontana Power House	F	1926-45
18746	F-26	Lytle Creek	At Highland Avenue	F	1938-45
18767	F-27	Lytle Creek	At Baseline Avenue	F	1938-45
18769	G-27	Lytle Creek	At Foothill Boulevard	F	1938-45
17980	G-27	E.Br.Lytle Creek	At San Bernardino	A	1929-45
17982	H-27	W.Br.Lytle Creek	At Colton	A	1929-45
18561	E-23	Day Creek	Near Etiwanda	A	1929-45
4572	E-21	Cucamonga Creek	Near Uplands	A-E	1927-28 & 1929-45
15985	M-23	Temescal Creek	Near Corona	A-E	1927-45
15991	L-23	Arlington Drain	0.4 Mile E. of McKinley	C	1941-45
5638	E-20	San Antonio Cr.	Near Claremont	A	1916-45
5628	E-20	San Antonio Cr.	Near Uplands	A	1901-16
4514	F-20	San Antonio Cr.	Mouth of Canyon	B	1931-45
15850	L-21	Chino Creek	Near Prado	A-E	1929-40
15728	N-18	Santiago Creek	Near Villa Park	A	1920-45
14513	O-16	Santiago Creek	At Santa Ana	A	1929-45



LEGEND

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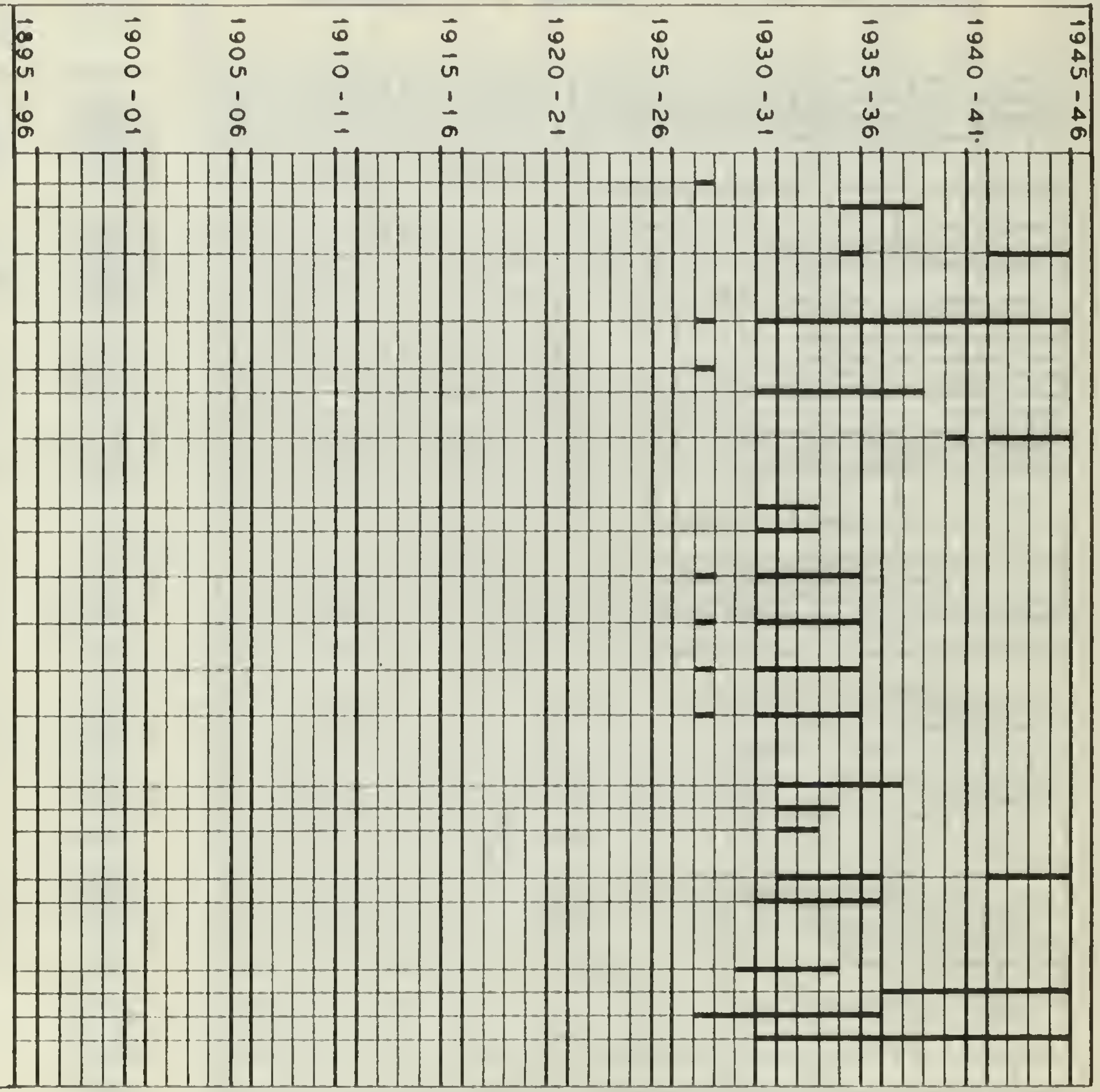
E " " State Division of Water Resources and predecessors.
F " " Fontana Union Water Company.

* Measurements during irrigation season only.

PERIODS OF STREAM FLOW RECORDS

SANTA ANA RIVER SYSTEM

STATION NUMBER	MAP INDEX	STREAM SYSTEM	RECORDING STATION	MEAS. BY	YEARS OF RECORD
13362	Q-17	Irvine Drainage	At Lane Road	C-E	1927-28, 1934-38, 1939-40 & 1941-45
13313	Q-16	Dolhi Drainage	Near Nowport Road	C-E	1927-28 & 1930-45
13262	Q-15	Adams Drainage	At Adams Road	C-E	1927-28, 1930-38, 1939-40 & 1941-45
14478	P-15	Newhope Drg.	Outlet	C	1930-33
14467	P-15	Newhope Drg.	So. of Smeltzer Avenue	C	1930-33
13222A	Q-14	4th Drain Ditch	W. of Santa Ana River at Adams Road	C-E	1927-28 & 1930-35
13222B	Q-15	3rd Drain Ditch	W. of Santa Ana River at Adams Road	C-E	1927-28 & 1930-35
13233	Q-15	2nd Drain Ditch	W. of Santa Ana River at Adams Road	C-E	1927-28 & 1930-35
13242	Q-15	1st Drain Ditch	W. of Santa Ana River at Adams Road	C-E	1927-28 & 30-35
589B	P-14	Wintersburg Spg.	At Talbert Avenue	C	1931-37
589C	P-14	Wintersburg Drg.	Near Edwards Street	C	1931-34
568	P-13	Drainage Ditch	Long Beach Country Club	C	1931-33
557	P-13	Drainage Ditch	Blue Bill Gun Club	C	1931-36 & 1941-45
1868	K-17	Carbon Creek	Near Olinda	C	1930-36
857	M- 9	Dominguez Channel	At Wilmington Avenue	B	1929-34
1290	I- 6	Ballona Creek	At Sawtelle Blvd.	B	1936-45
1281	J- 6	Ballona Creek	At Centinella Blvd.	A-B	1927-36
2416	H- 3	Topanga Canyon	At State Highway	A-B	1930-45

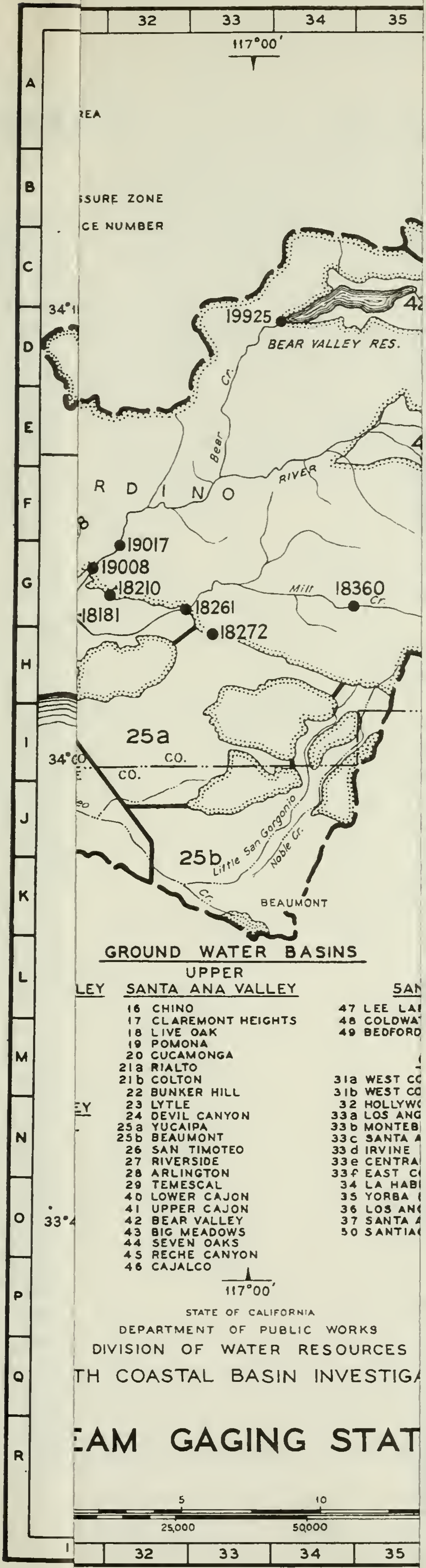


LEGEND:

A Measurements by United States Geological Survey.
B " " Los Angeles County Flood Control District.
C " " Orange County Flood Control District.
D " " Pasadena Water Department.
E " " State Division of Water Resources and Predecessors.

PERIODS OF STREAM FLOW RECORDS

STREAMS FLOWING DIRECT TO OCEAN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25b
Little San Gorgonio
Noble Cr.
Cr.
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GROUND WATER BASINS
UPPER
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SANTA ANA VALLEY
SAN
16 CHINO
17 CLAREMONT HEIGHTS
18 LIVE OAK
19 POMONA
20 CUCAMONGA
21a RIALTO
21b COLTON
22 BUNKER HILL
23 LYTLE
24 DEVIL CANYON
25a YUCAIPA
25b BEAUMONT
26 SAN TIMOTEO
27 RIVERSIDE
28 ARLINGTON
29 TEMESCAL
40 LOWER CAJON
41 UPPER CAJON
42 BEAR VALLEY
43 BIG MEADOWS
44 SEVEN OAKS
45 RECHE CANYON
46 CAJALCO
47 LEE LA
48 COLDWA
49 BEDFORD
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DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
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CHAPTER IV. EVALUATION OF OVERDRAFT OR EXCESS

As illustrated by the well graphs of Plates 8 to 19, inclusive,* the water table in all basins rises during the rainy winter season when extractions are small, and falls during the summer. In virtually all basins it becomes progressively lower throughout the dry period of a cycle, and rises progressively during the wet period. If average annual net extractions from the ground water during the cycle, and average annual net supply to it are equal, total rise and total fall are equal, and the water table stands at the same elevation at the beginning and end of the cycle. Where average net supply is the smaller, however, the elevation is lower at the end than at the beginning.

The fact that the water table in a basin has so dropped in some past cycle does not necessarily indicate an overdraft. In some basins outflow, as rising water or underflow, responds quickly and in relatively large amount to changes in water table elevation. Where this is true the decrease in average outflow during a future cycle, resulting from lower average elevation during the cycle, may be sufficient to balance excess extractions, without the water table falling below the level from which pumping is feasible. Where it is apparent that the balance will not be long delayed, an overdraft is not considered to exist. Since a higher water table correspondingly increases outflow, it is equally true that in such a basin there is no excess. In a few basins lack of storage capacity limits the period during which either overdraft or excess can persist. In Raymond Basin Area, which includes Monk Hill Basin and Pasadena and Santa Anita Areas, extractions are limited to safe yield by court decree, and in Beaumont Basin the drop in water table elevation is controlled by a court limitation on export.

In those basins where no legal limitation is in effect, and from which both surface and subsurface outflow are little affected by water table elevation, or where a considerable period of time must elapse before outflow will change enough to bring about a balance between supply and demand, a decrease in the amount in storage between the beginning and end of the cycle is considered to indicate an overdraft, provided that long time mean net supply to the ground water under present conditions is no greater than historic mean net supply during the cycle, or present extractions are no less than they averaged during the cycle.

If present conditions, both as regards supply and extractions, were identical with those which maintained throughout the cycle, average annual decrease in the amount in storage during the cycle would measure the amount of the overdraft. Generally, however, present net extractions are somewhat greater than the average during either of the cycles of record used herein. If this is the only change which has occurred, present overdraft is greater than average annual change in storage by the difference in net annual extractions. On the other hand, where the net supply has been increased through spreading, through greater

* Location of wells involved are shown on Plate 20.


LEGEND
WATERSHED BOUNDARY
EDGE OF NONWATER - BEARING AREA
GROUND WATER BASIN BOUNDARY
SUB-AREA BOUNDARY
APPROXIMATE BOUNDARY OF PRESSURE ZONE
6 GROUND WATER BASIN REFERENCE NUMBER
2416 STREAM GAGING STATION
GROUND WATER BASINS
SAN FERNANDO VALLEY
1 SAN FERNANDO
2 SYLMAR
3 TUJUNGA
4 PACOIMA
5 VERDUGO
38 BULL CANYON
39 LITTLE TUJUNGA
SAN GABRIEL VALLEY
6 MAIN SAN GABRIEL
7 MONK HILL
8a PASADENA
8b SANTA ANITA
9 UPPER CANYON
10 LOWER CANYON
11 GLENDORA
12 WAY - HILL
13 SAN DIMAS
14 FOOTHILL
15 PUENTE
30 SPADRA
UPPER SANTA ANA VALLEY
16 CHINO
17 CLAREMONT HEIGHTS
18 LIVE OAK
19 POMONA
20 CUCAMONGA
21a RIALTO
21b COLTON
22 BUNKER HILL
23 LYTLE
24 DEVIL CANYON
25a YUCAIPA
25b BEAUMONT
26 SAN TIMOTEO
27 RIVERSIDE
28 ARLINGTON
29 TEMESCAL
40 LOWER CAJON
41 UPPER CAJON
42 BEAR VALLEY
43 BIG MEADOWS
44 SEVEN OAKS
45 RECHE CANYON
46 CAJALCO
UPPER SANTA ANA VALLEY
47 LEE LAKE
48 COLDWATER
49 BEDFORD
COASTAL PLAIN
31a WEST COASTAL PLAIN - NORTH
31b WEST COASTAL PLAIN - SOUTH
32 HOLLYWOOD
33a LOS ANGELES
33b MONTEBELLO
33c SANTA ANA
33d IRVINE
33e CENTRAL COASTAL PLAIN PRESSURE
33f EAST COASTAL PLAIN PRESSURE
34 LA HABRA
35 YORBA LINDA
36 LOS ANGELES NARROWS
37 SANTA ANA NARROWS
50 SANTIAGO
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SOUTH COASTAL BASIN INVESTIGATION
STREAM GAGING STATIONS
SCALE 0 5 10 15 MILES
FEET 0 25,000 50,000 75,000
PACIFIC OCEAN
San Pedro Bay
Santa Monica Bay
LOS ANGELES
LONG BEACH
SANTA MONICA
SAN FERNANDO
POMONA
CORONA
RIVERSIDE
SAN BERNARDINO
SANTA ANA
BEAUMONT
SAN GABRIEL MTS.
SAN BERNARDINO MTS
SANTA MONICA MTS.
SANTA ANA MTS.
PUENTE HILLS
SAN JOSE HILLS
SAN JOAQUIN HILLS
SAN PEDRO HILLS
VERDUGO MTS
Whittier Narrows
Prado Dam
Riverside Narrows
Hansen Dam
Sepulveda Dam
Santa Fe Dam
San Gabriel Dams
BEAR VALLEY RES
LAKE ELSINORE
Lake Mathews
LOS ANGELES CO
VENTURA CO
ORANGE CO
RIVERSIDE CO
SAN BERNARDINO CO
118°30'
118°00'
117°30'
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34°00'
33°45'

CHAPTER IV. EVALUATION OF OVERDRAFT OR EXCESS

As illustrated by the well graphs of Plates 8 to 19, inclusive,* the ıter table in all basins rises during the rainy winter season when tractions are small, and falls during the summer. In virtually all sins it becomes progressively lower throughout the dry period of a cle, and rises progressively during the wet period. If average annual t extractions from the ground water during the cycle, and average nual net supply to it are equal, total rise and total fall are equal, and e water table stands at the same elevation at the beginning and end of e cycle. Where average net supply is the smaller, however, the elevan is lower at the end than at the beginning.

The fact that the water table in a basin has so dropped in some past cle does not necessarily indicate an overdraft. In some basins outflow, rising water or underflow, responds quickly and in relatively large nount to changes in water table elevation. Where this is true the crease in average outflow during a future cycle, resulting from lower erage elevation during the cycle, may be sufficient to balance excess tractions, without the water table falling below the level from which mping is feasible. Where it is apparent that the balance will not be ng delayed, an overdraft is not considered to exist. Since a higher water ble correspondingly increases outflow, it is equally true that in such basin there is no excess. In a few basins lack of storage capacity limits e period during which either overdraft or excess can persist. In aymond Basin Area, which includes Monk Hill Basin and Pasadena d Santa Anita Areas, extractions are limited to safe yield by court cree, and in Beaumont Basin the drop in water table elevation is ntrolled by a court limitation on export.

In those basins where no legal limitation is in effect, and from which th surface and subsurface outflow are little affected by water table evation, or where a considerable period of time must elapse before tflow will change enough to bring about a balance between supply and mand, a decrease in the amount in storage between the beginning and d of the cycle is considered to indicate an overdraft, provided that long ne mean net supply to the ground water under present conditions is greater than historic mean net supply during the cycle, or present tractions are no less than they averaged during the cycle.

If present conditions, both as regards supply and extractions, were entical with those which maintained throughout the cycle, average nual decrease in the amount in storage during the cycle would meas- e the amount of the overdraft. Generally, however, present net extrac- ns are somewhat greater than the average during either of the cycles record used herein. If this is the only change which has occurred, esent overdraft is greater than average annual change in storage by e difference in net annual extractions. On the other hand, where the t supply has been increased through spreading, through greater

* Location of wells involved are shown on Plate 20.

importations or by other means, overdraft under present conditions is less by the amount of the increase. In other words, overdraft is the average annual amount by which the quantity in storage would have decreased had present conditions affecting supply and demand maintained throughout the cycle.

Evaluation of overdraft does not require, moreover, that a record of water table fluctuations throughout a complete cycle be available. Any period in which change in storage can be determined provides the basis for an estimate. If average annual net extractions during such a base period were the same as those of the present, and average annual net supply the same as the long-time mean, average annual decrease in the amount in storage during the base period would be the same as that during a complete cycle of supply under present conditions, and would measure the overdraft. Where they are not the same, under the conditions set forth in the preceding paragraph the difference between present and base period average net extractions increases the calculated overdraft, and the difference between long-time mean and base period average net supply decreases it, each by the amount of the respective difference.

For reasons discussed in Chapter V, the 11-year period, 1927-28 to 1937-38, inclusive, is one in which an acceptable estimate of change in storage is possible. In this period, too, average annual precipitation is generally not far different from the long-time mean, and the modification required in order to account for differences in items dependent upon the weather is therefore relatively small.

While overdraft results in, and in nearly all cases is measured by change in storage in the ground water basin, it is actually, because of interconnection between surface and ground water systems, an overdraft on the entire supply to the overlying area. More water leaves the area by evaporation, transpiration, export, surface outflow and underflow, than reaches it in the form of precipitation, stream-flow, import and underflow. Because of the fact that direct determination of percolation to the ground water and net extractions from it is difficult, the above items are used instead, where such procedure is applicable. In the pressure areas of Central and East Coastal Plain, however, where percolation to the ground water from the surface is negligible, it is the difference between present and base period average annual extractions which is significant. Under any procedure, overdraft is the average amount which must come annually from underground storage to make up the difference between supply and demand.

Changes in storage during the base period, modifications due to differences between base period average annual and long-time mean annual amounts of water entering and leaving the areas under present conditions, and resulting values of excess or overdraft as derived in Chapter VI, are presented in Table 5. Here the modifier and the overdraft or excess are rounded to two significant figures.

In the last nine basins listed as part of the Upper Santa Ana Valley group, in Chapter II, there is either no development, or so little that obviously no overdraft exists. These basins are therefore treated as a part of the area tributary to lower basins, and are not considered separately.

The Department of Public Works has been appointed referee in a suit recently filed in the Superior Court for Los Angeles County, having as its objective the limitation of extractions from the ground water of West Coastal Plain to the safe yield. Over a large part of this area the water table has remained below sea level for many years, and a part of the supply to the ground water has been of a quality unsuitable for general use. Because of this, an evaluation of overdraft involves a far more complex and detailed study than is required elsewhere. In order that publication of results for the remainder of South Coastal Basin may not be delayed until such time as a detailed study is completed, no value of overdraft in West Coastal Plain is here presented. The fact that the water table has long sloped landward from the area of contamination, and that the increase in slope has recently been accelerated by large increase in extractions, shows clearly, however, that the overdraft is large and the situation critical.

Present conditions as here defined are those of 1944-45. Reference to Table 10 indicates that increase in consumptive use is generally relatively slow. Import and export of water, both of which are subject to arbitrary increase or decrease, may in some cases change materially within a year as may export of sewage. Outflow may be arbitrarily increased through paving of channels or decreased through spreading or other conservation measures. Until sufficient time has passed to provide another period suitable for use as a base, it is believed that the values of overdraft presented in Table 5 can, without introducing material error, be brought up to date at any time by adding the increase in export of water and sewage since 1944-45, and subtracting the increase in import and the net salvage where it is significant.

TABLE 5. ESTIMATED ANNUAL OVERDRAFT OR EXCESS BY BASINS UNDER PRESENT CONDITIONS

(Acre-feet)

Basin name and number	*Average annual change in storage during base period* [a]	*Modifier* [b]	*Overdraft*	*Excess*
Verdugo Basin (5)	+690	—930	240	----
San Fernando Valley Area [c] (1, 2, 3, 4, 38 and 39)	+9,370	+16,000	----	25,000 [d]
Raymond Basin Area				
Western Unit [ce] (7 and 8a)	—5,810	----	0	0
Eastern Unit [f] (8b)	----	----	0	0
Glendora Basin (11)	+250	+310	----	560
Way Hill Basin (12)	+220	+490	----	710
Foothill Basin [g] (14)	0	----	0	0
San Dimas Basin (13)	+110	+700	----	810
Spadra Basin (30)	—840	+10	830	----
Puente Basin (15)	—340	+1,400	----	1,100
Central San Gabriel Valley Area [cg] (6, 9 and 10)	+4,360	----	0	0
La Habra Basin [h] (34)	750	+220	530	----
Lower Los Angeles and San Gabriel Rivers Area [c] (32, 33a, 33b, 33e, and 36)	—12,900	+900	12,000	----
Claremont Heights Basin (17)	+270	—1,700	1,400	----
Live Oak Basin (18)	+10	+200	----	210
Pomona Basin (19)	—2,760	+560	2,200	----
Cucamonga Basin (20)	—400	+690	----	290
Rialto Basin (21a)	—340	+120	220	----
Lower Cajon Basin [i] (40)	0	----	0	0
Lytle Basin [f] (23)	+3,460	----	0	0
Devil Canyon Basin [i] (24)	+1,280	----	0	0
Yucaipa Basin (25a)	—2,350	+1,200	1,200	----
Beaumont Basin [f] (25b)	—740	----	0	0
San Timoteo Basin [j] (26)	+230	----	0	0
Bunker Hill Basin [g] (22)	—520	----	0	0
Colton-Reche Canyon Area [cg] (21b and 45)	—130	----	0	0
Riverside-Arlington Area [cg] (27 and 28)	—3,760	----	0	0
Temescal Basin [i] (29)	+270	----	0	0
Chino Basin (16)	—22,810	+4,800	18,000	----
Irvine Basin (33d)	—3,120	+420	2,700	----
Lower Santa Ana River Area [c] 33c, 33f, 35, 37 and 50)	—14,690	+4,700	10,000	----

[a] Eleven-year period, 1927-28 to 1937-38, inclusive.
[b] Effect of difference between historic base period average and long-time mean under present conditions.
[c] Basins grouped for reasons stated in Chapter VI.
[d] Includes water available to Los Angeles Aqueduct in Mono Basin and Owens Valley. See discussion of excess in San Fernando Valley Area in Chapter VI.
[e] Required import calculated.
[f] Permissible export calculated.
[g] Surface outflow calculated.
[h] Average of 20- and 21-year mean annual values used.
[i] Subsurface outflow calculated.
[j] Thirty-two year period considered cycle of long-time mean supply.

COMBINED OVERDRAFT OR EXCESS

The interrelationship between basins, while especially marked in the case of the groups presented as a unit in Table 5, is common to other groups as well. Lowering of the water table resultant from a long continued overdraft on any basin influences the interchange of water by export and import, and in some degree affects outflow from an upper basin to one downstream, thus decreasing overdraft on one basin and correspondingly increasing that on another. For this reason, overdraft on the group is often more significant than that on each of the basins considered individually. The same is true where the rise resulting from an excess is more rapid in one basin than another, or where an excess and an overdraft exist in interrelated basins.

Los Angeles River Ground Water System

Above Los Angeles Narrows, only Verdugo Basin has been treated separately. Export from that basin to San Fernando Valley contributes to the overdraft in Verdugo Basin and to the excess in the valley. While extractions for export are so located that their effect will probably be long delayed, continued overdraft must eventually result in reduced export, with a corresponding reduction in overdraft in Verdugo Basin and excess in San Fernando Valley. The combined annual excess above the Narrows is about 25,000 acre-feet.

As brought out in detailed discussion in Chapter VI, this excess includes a large supply available in Owens Valley and Mono Basin, and is potential rather than actual insofar as its effect on the rising water at the Narrows is concerned. Furthermore, even if the outflow of rising water were increased through importing and spreading water not now required for use, the increase in percolation to the ground water of the Coastal Plain would be negligible, and since direct diversion to use of the rising water is infeasible under present conditions, there is no point in deriving a combined excess in San Fernando Valley and Coastal Plain Basins.

San Gabriel River Ground Water System

In this system Central San Gabriel Valley Area and La Habra Basin, both as regards surface and subsurface flow, are tributary to Lower Los Angeles and San Gabriel Rivers Area. Western and Eastern Units of Raymond Basin Area, and Glendora, Way Hill, San Dimas and Puente Basins are tributary to Central San Gabriel Valley Area. Foothill Basin is tributary to San Dimas Basin, and Spadra Basin* to Puente Basin. In Spadra* and La Habra Basins, which are overdrawn, the water table will fall if present conditions of supply and demand continue, until the resulting decrease in subsurface outflow balances the present overdraft in those basins. This will decrease the supply to Lower Los Angeles and San Gabriel Rivers Area directly in one case, and to Puente Basin, Central San Gabriel Valley Area and the lower area successively in the other. In Glendora, Way Hill, San Dimas and Puente Basins, on the other hand, an excess is available, and so long as present supply and demand conditions continue, a progressive rise in the water table, and an increase in average annual outflow to Central San Gabriel Valley, and

* Geologically part of Upper Santa Ana Valley Group, as listed in Chapter II.

thence to Lower Los Angeles and San Gabriel Rivers Area will occur. The net result, if present demands continue until all tributary basins are at equilibrium, will be an increase of about 2,300 acre-feet in annual flow at Whittier Narrows, and a decrease of about 1,800 acre-feet in the overdraft below the Narrows. This would require, however, that demand remain as it is for a long time in the future. It is more probable that a part of the excess above Whittier Narrows will be accounted for by increased demand in the tributary basins, and only a part will benefit the Coastal Plain. The values presented in Table 5 represent the amount by which demand must decrease or increase in overdrawn or oversupplied basins, respectively, if water table elevations are to remain substantially as at present. If, on the other hand, demand is unchanged, and the water table is permitted to fall or rise without limit, neither excess nor overdraft exists in the tributary basins after equilibrium is reached, and the annual overdraft on Lower Los Angeles and San Gabriel Rivers Area is about 10,000 acre-feet, or about 2,000 acre-feet less than the value for that area considered independently as shown in Table 5.

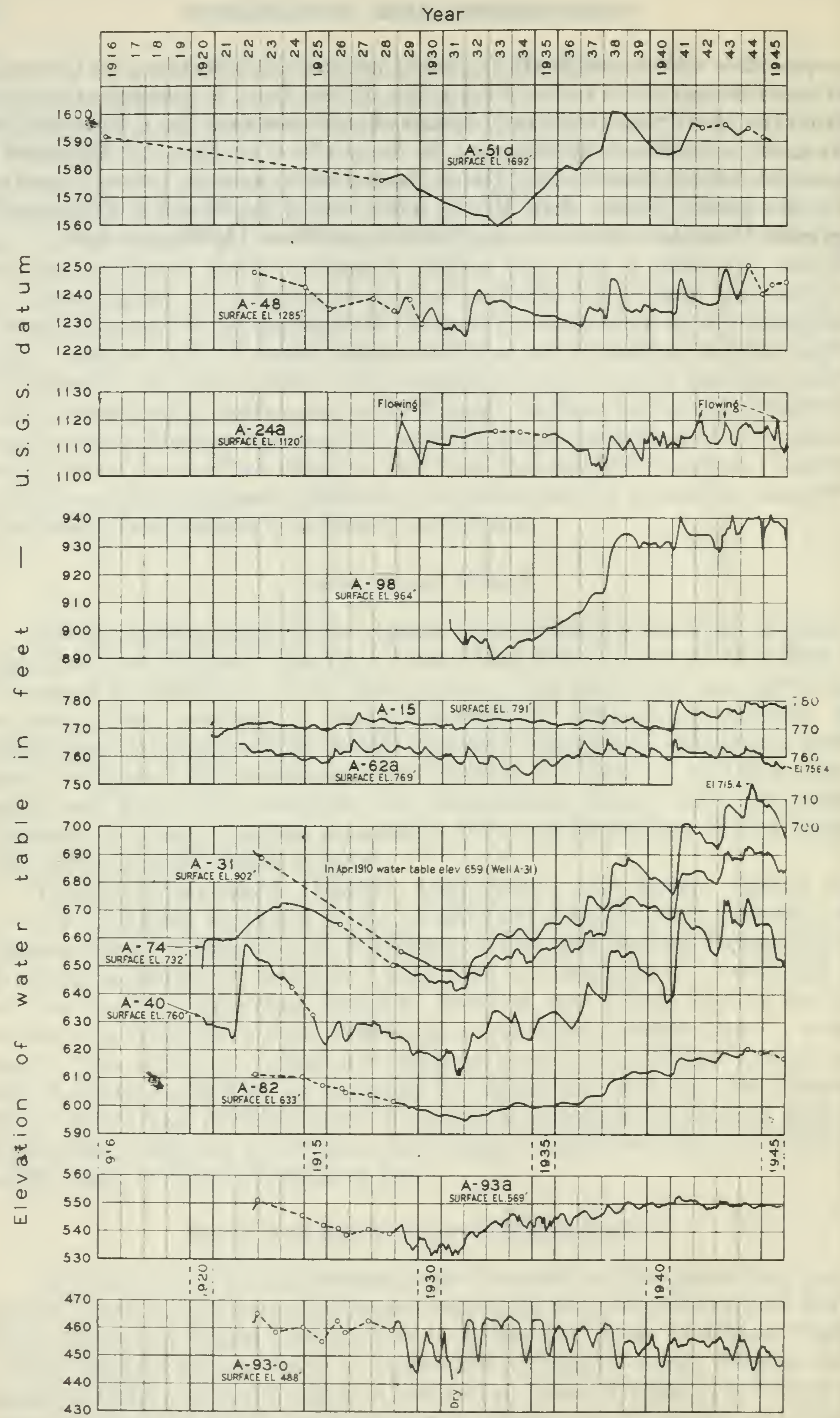
Chino Basin Group

While outflow from Chino Basin contributes to the flow of Santa Ana River, no evidence has been found that the amount of this flow is influenced by elevation of the water table. This indicates that lowering the water table enough to produce significant decrease in outflow, as subsurface or rising water, would preclude continued extraction from many wells, and thus automatically decrease the demand on the ground water, and hence the overdraft. For this reason, Chino Basin and those tributary to it are grouped separately from the remainder of the Santa Ana River ground water system.

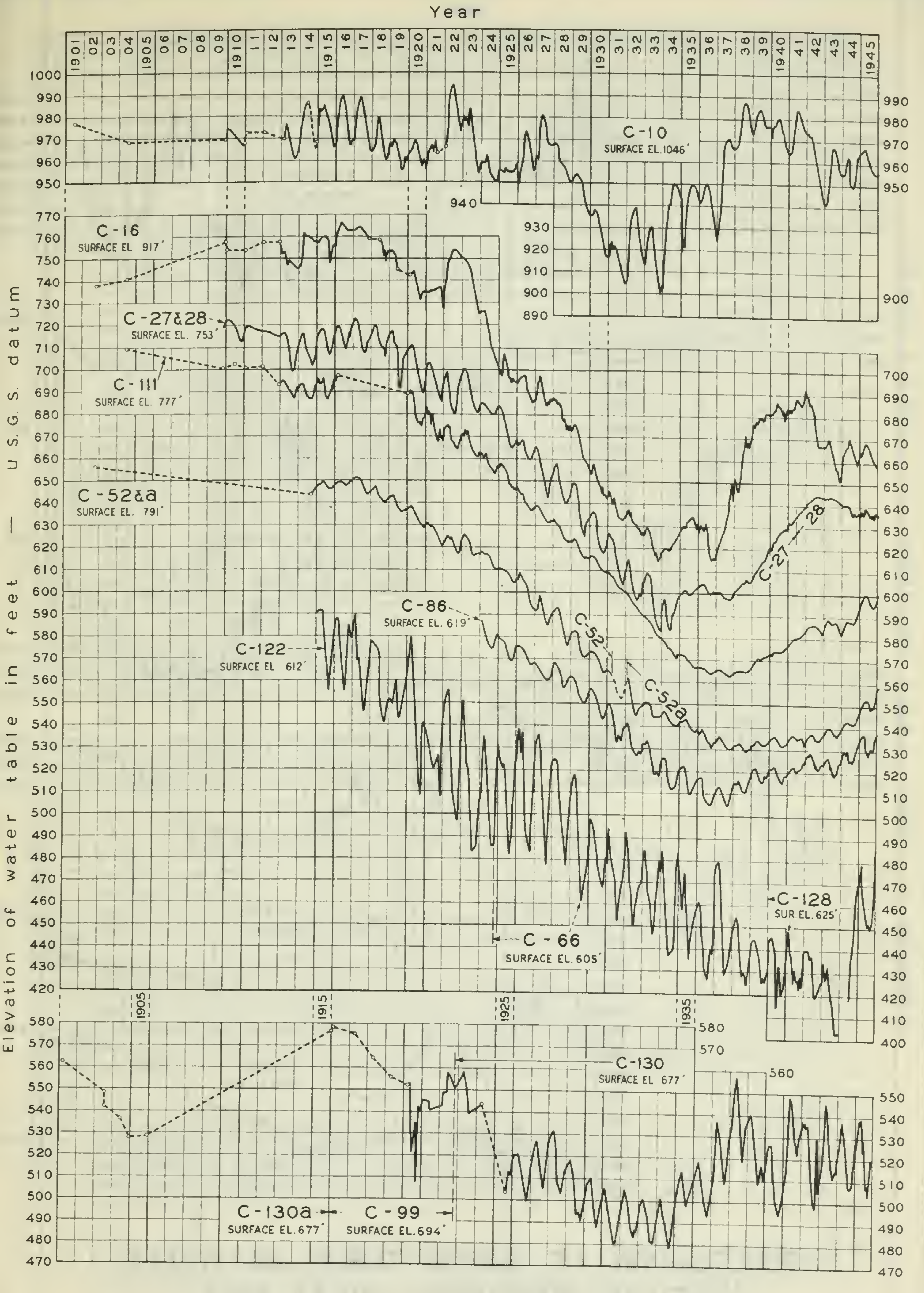
Pomona, Claremont Heights, Cucamonga and Rialto Basins are directly tributary to Chino Basin, while Live Oak Basin is tributary to Pomona Basin. Subsurface flow between Chino and Spadra Basins might be either increased or decreased with long continuance of overdrafts in the two basins. Claremont Heights, Pomona, and Chino Basins are all overdrawn, while Live Oak, Cucamonga and Rialto Basins show a small excess. The tributary basins are interconnected with Chino Basin, not only through underflow, as discussed in connection with the San Gabriel River Group, but perhaps more significantly through export and import by entities producing water from both basins. Combined annual overdraft in the group is about 21,000 acre-feet.

Santa Ana River Ground Water System

In the portion of this system not discussed in the preceding paragraphs, Irvine and Chino Basins are tributary to Lower Santa Ana River Area, Temescal Basin and Riverside-Arlington Area to Chino Basin, Colton-Reche Canyon Area to Riverside-Arlington Area, Bunker Hill Basin to Colton-Reche Canyon Area, Lytle, Lower Cajon, Devil Canyon and San Timoteo Basins to Bunker Hill Basin, and Yucaipa and Beaumont Basins are tributary to San Timoteo Basin. Of all of these, only Yucaipa and Irvine Basins and Lower Santa Ana River Area are considered to be overdrawn. In effect, all others, except Beaumont Basin where a legal limitation on export from South Coastal Basin is considered to preclude either overdraft or excess, are already combined in the evaluation of overdraft in Lower Santa Ana River Area. If present extractions from the overdrawn tributary basins should continue until the overdraft in each is balanced by decrease in subsurface outflow, as discussed in connection with San Gabriel River ground water system, annual overdraft on the Lower Santa Ana River Area would be about 4,000 acre-feet greater than the value shown in Table 5, or about 14,000 acre-feet.

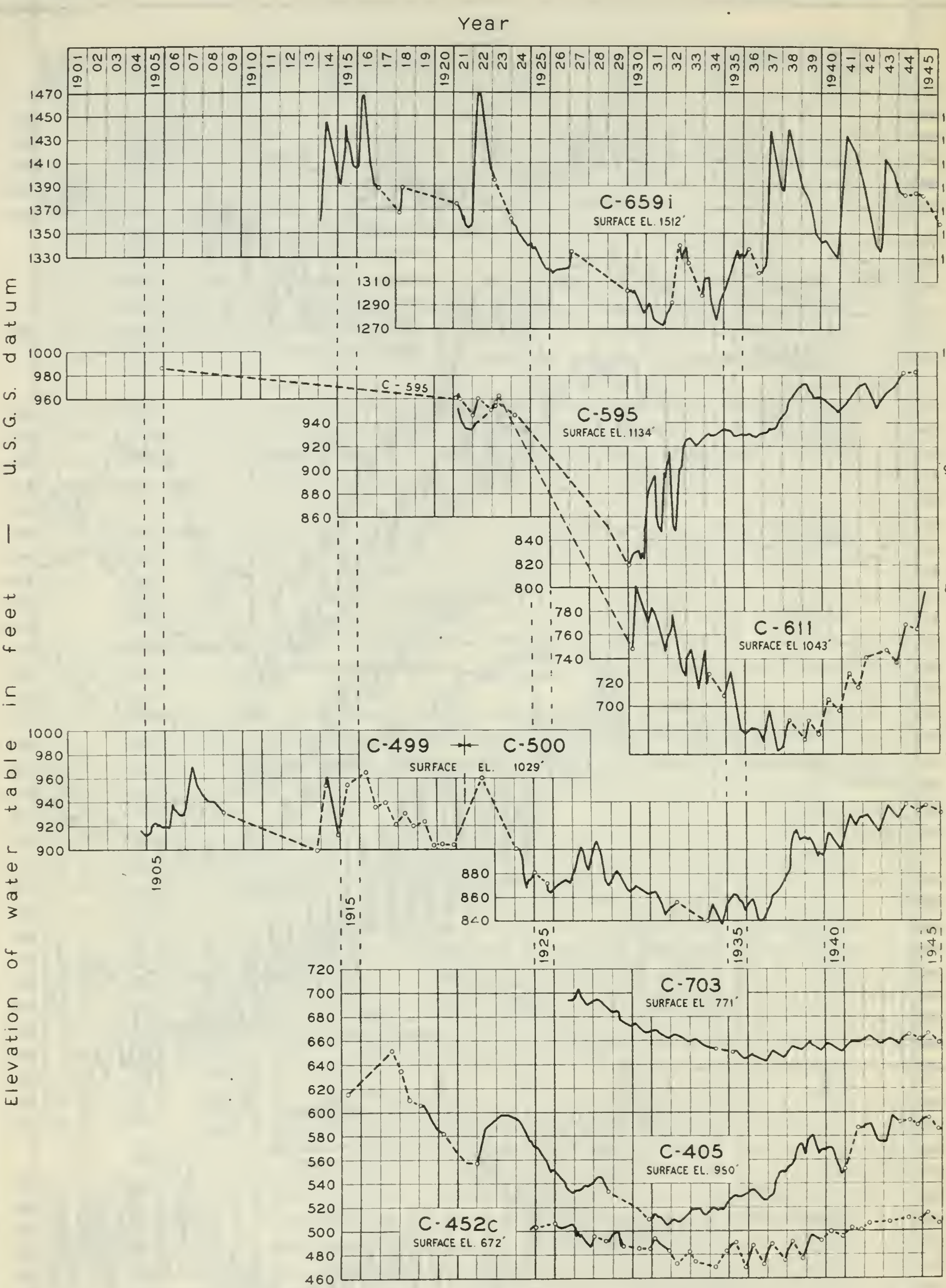


FLUCTUATION OF WATER TABLE AT WELLS
SAN FERNANDO VALLEY AREA & VERDUGO BASIN

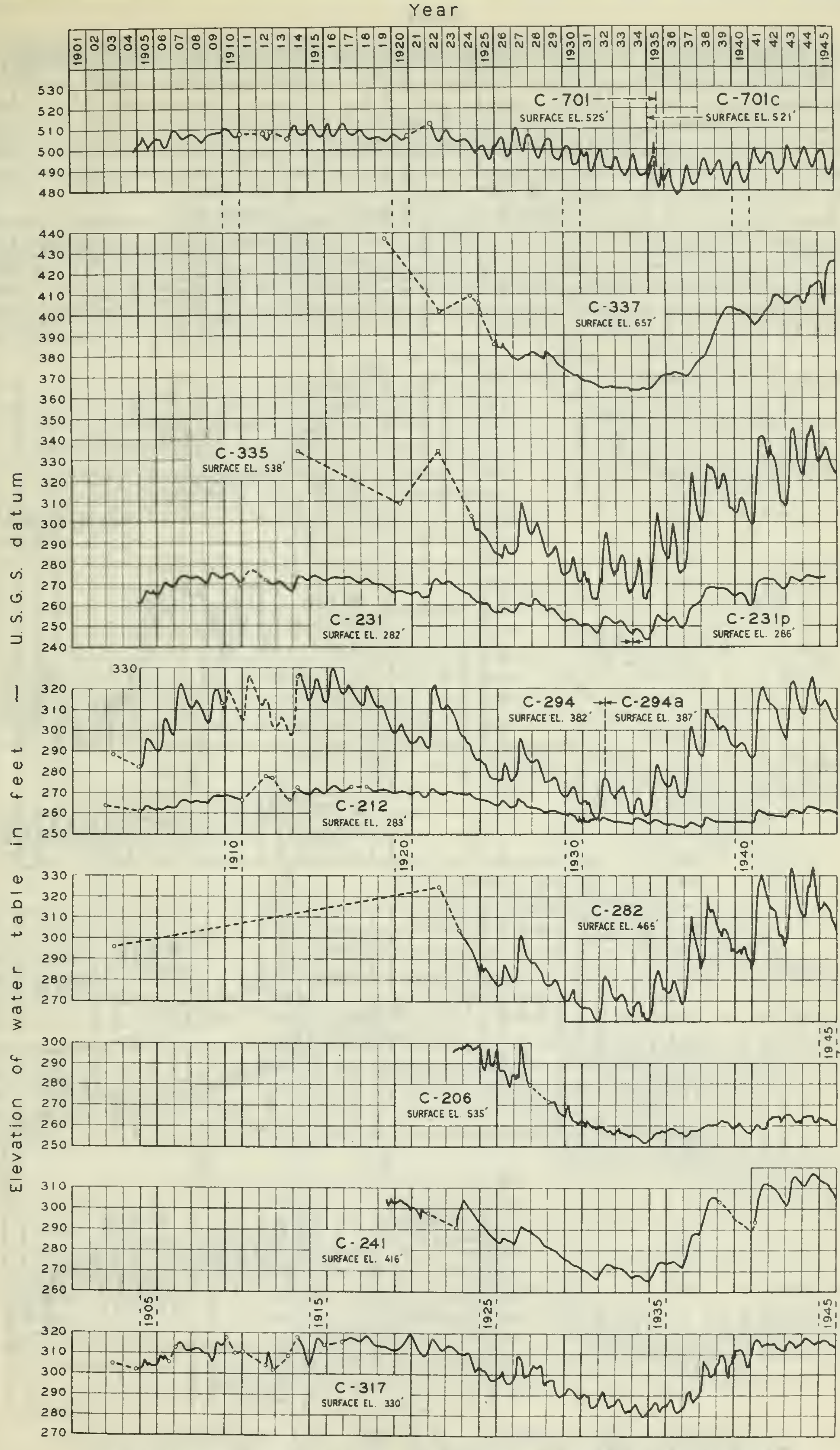


FLUCTUATION OF WATER TABLE AT WELLS
RAYMOND BASIN AREA

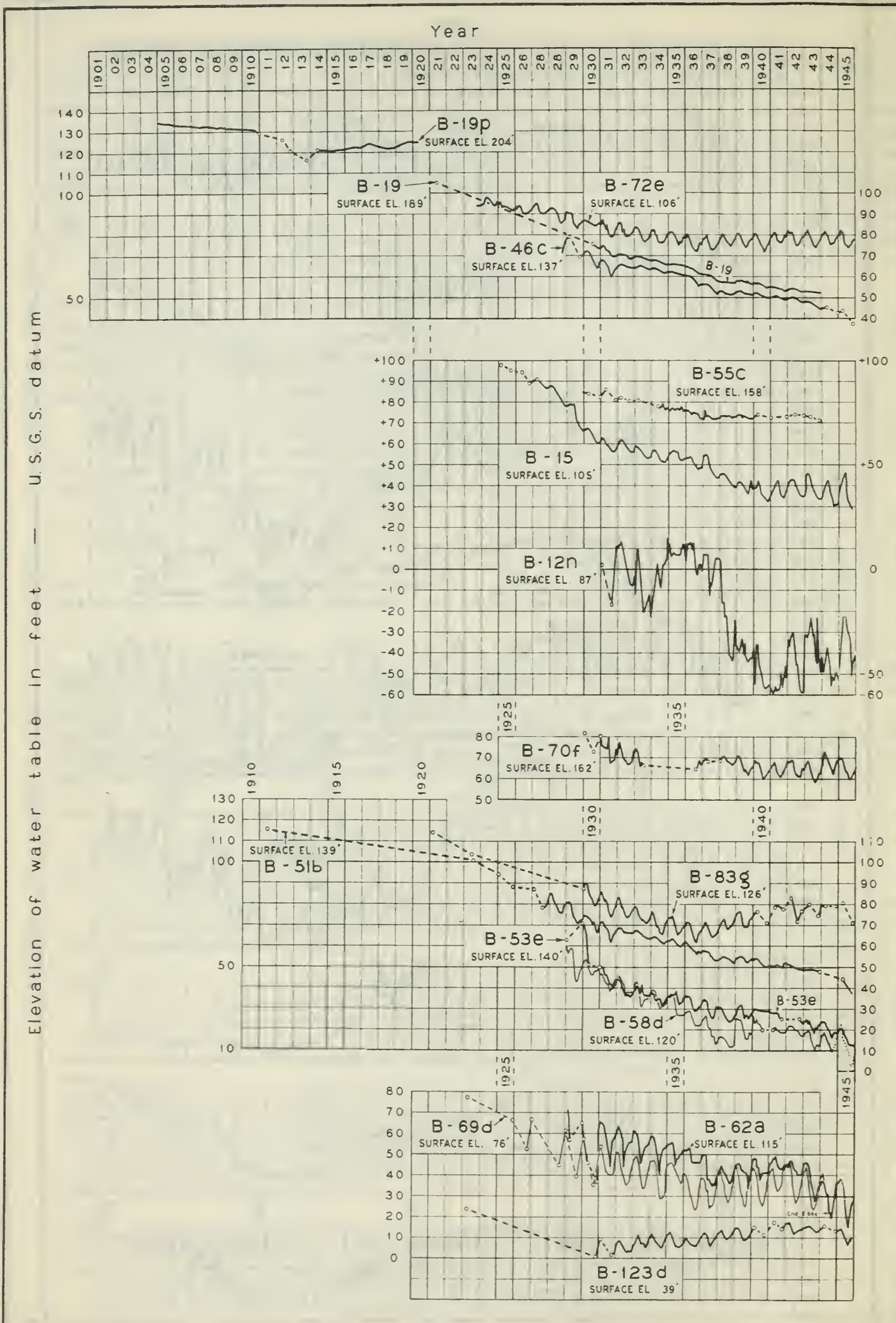
PLATE 10



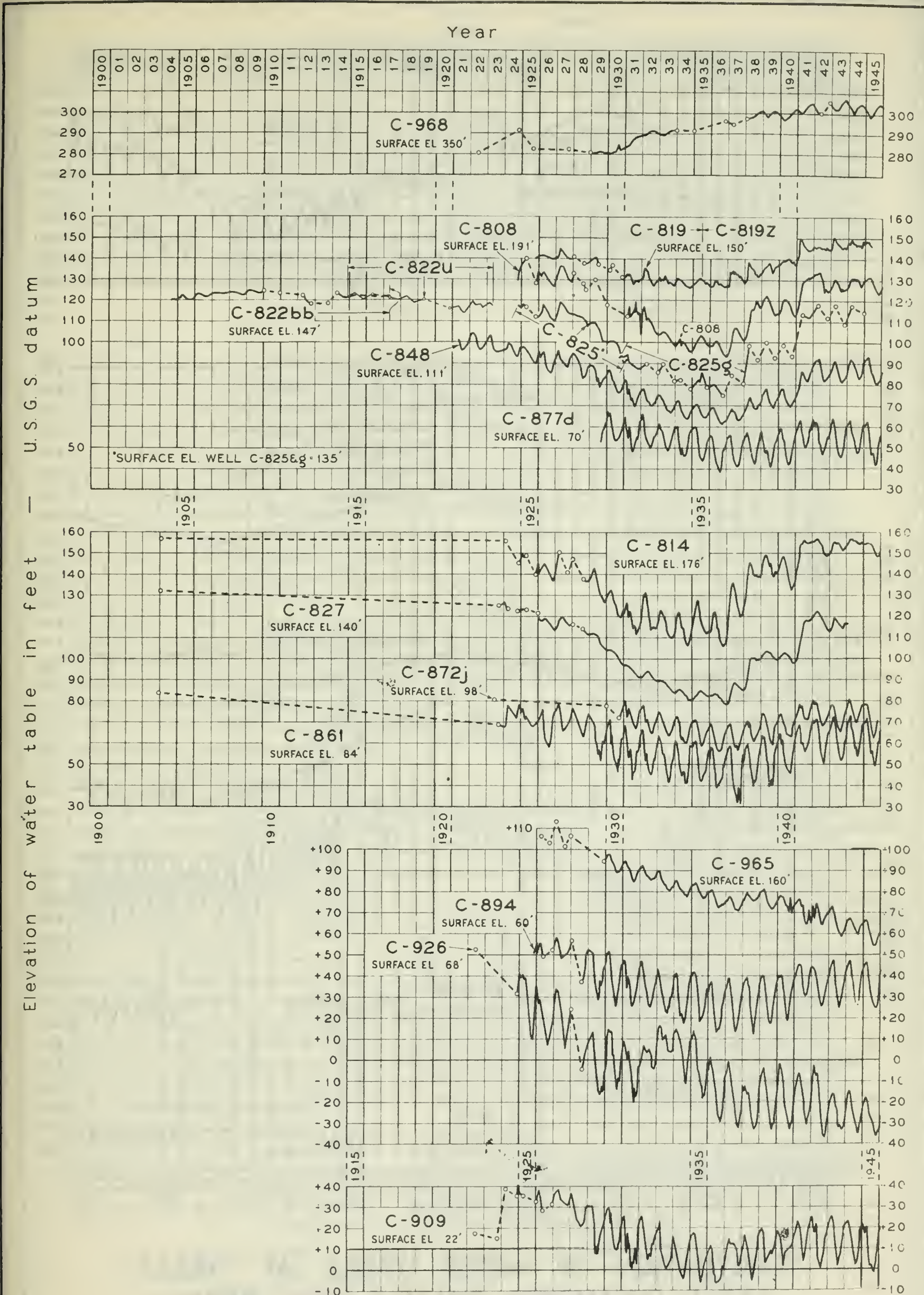
FLUCTUATION OF WATER TABLE AT WELLS
EASTERN SAN GABRIEL VALLEY AREA



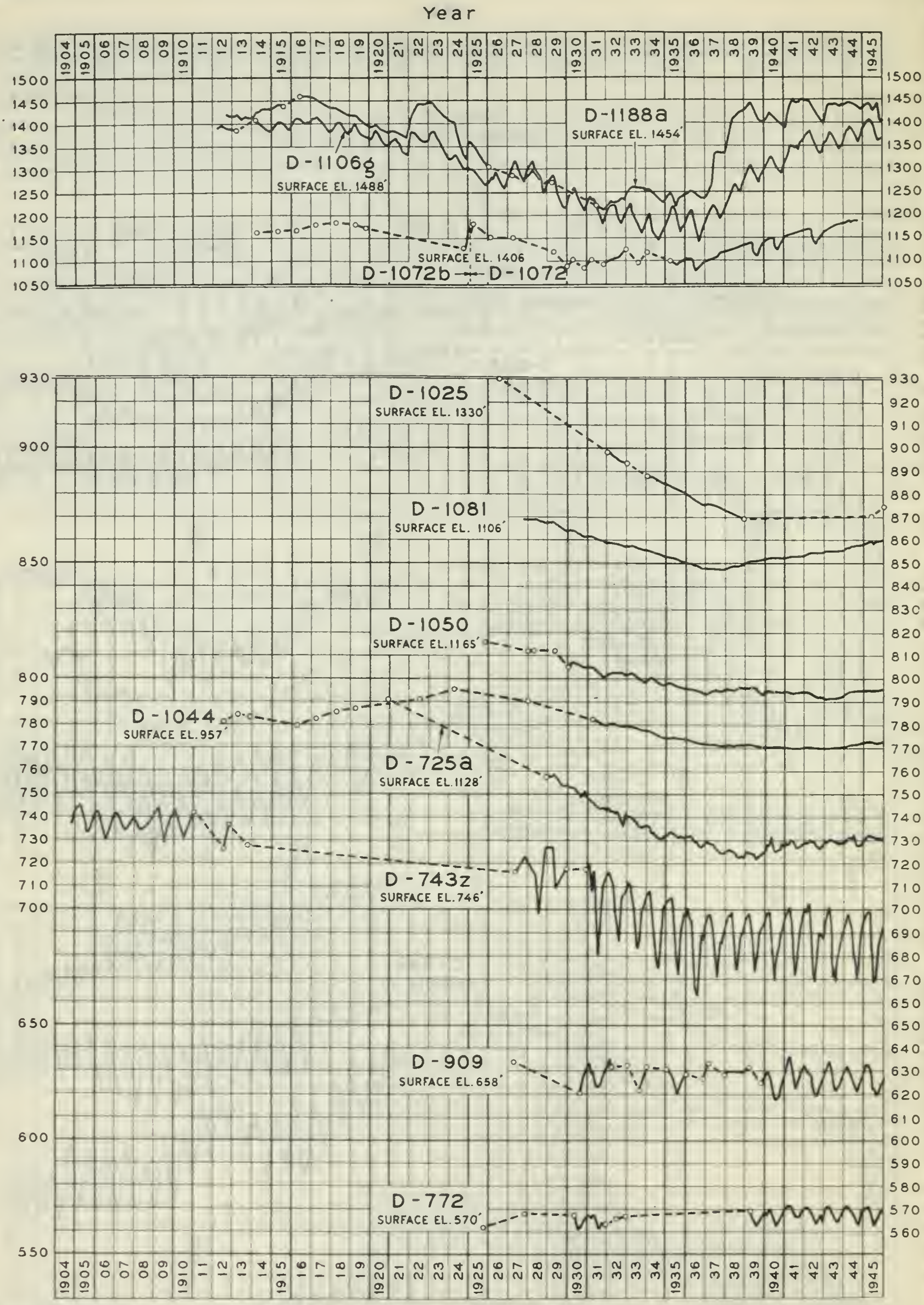
FLUCTUATION OF WATER TABLE AT WELLS
SAN GABRIEL AND PUENTE BASINS



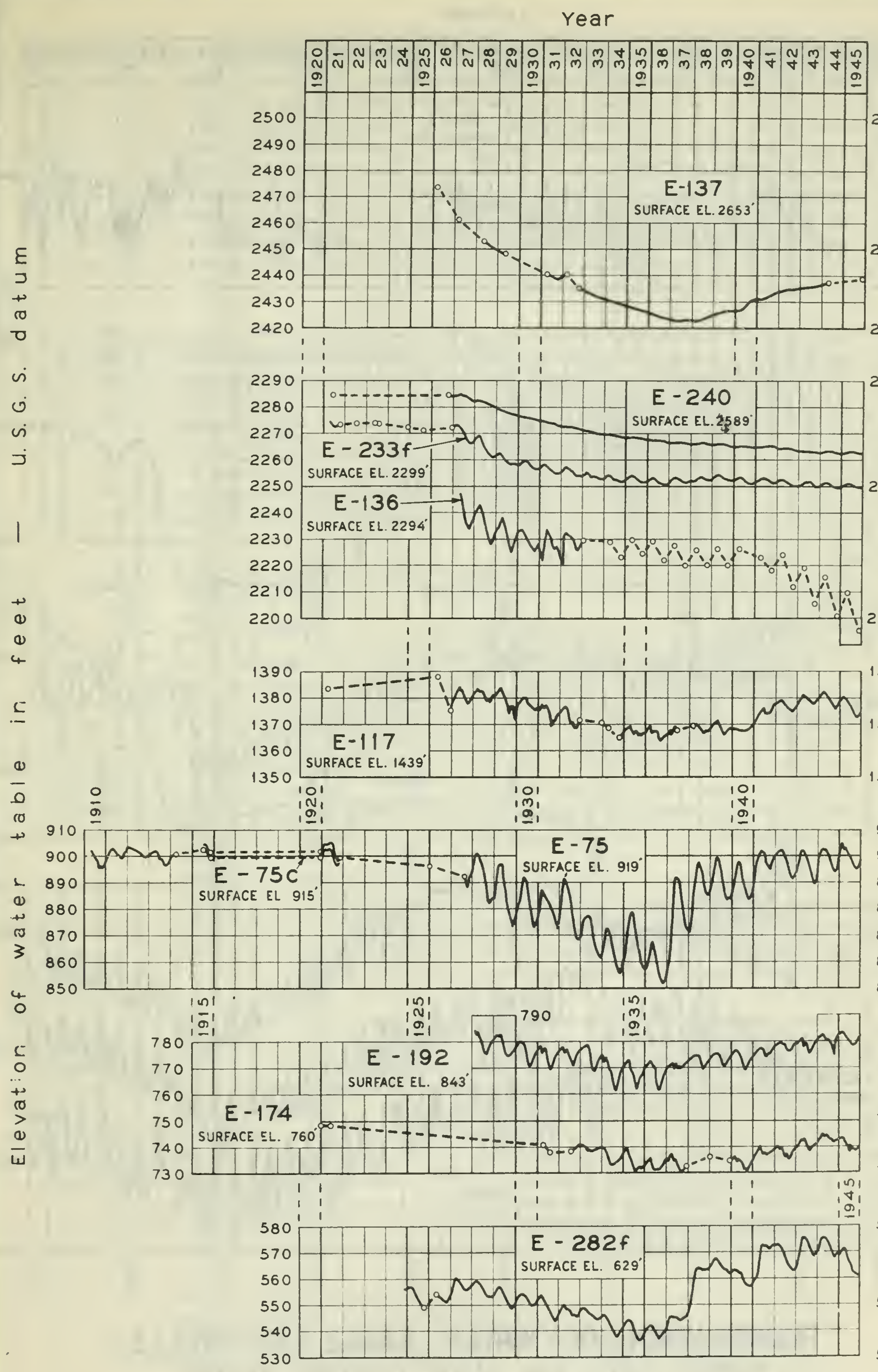
FLUCTUATION OF WATER TABLE AT WELLS
CENTRAL COASTAL PLAIN — WEST HALF



FLUCTUATION OF WATER TABLE AT WELLS
CENTRAL COASTAL PLAIN — EAST HALF



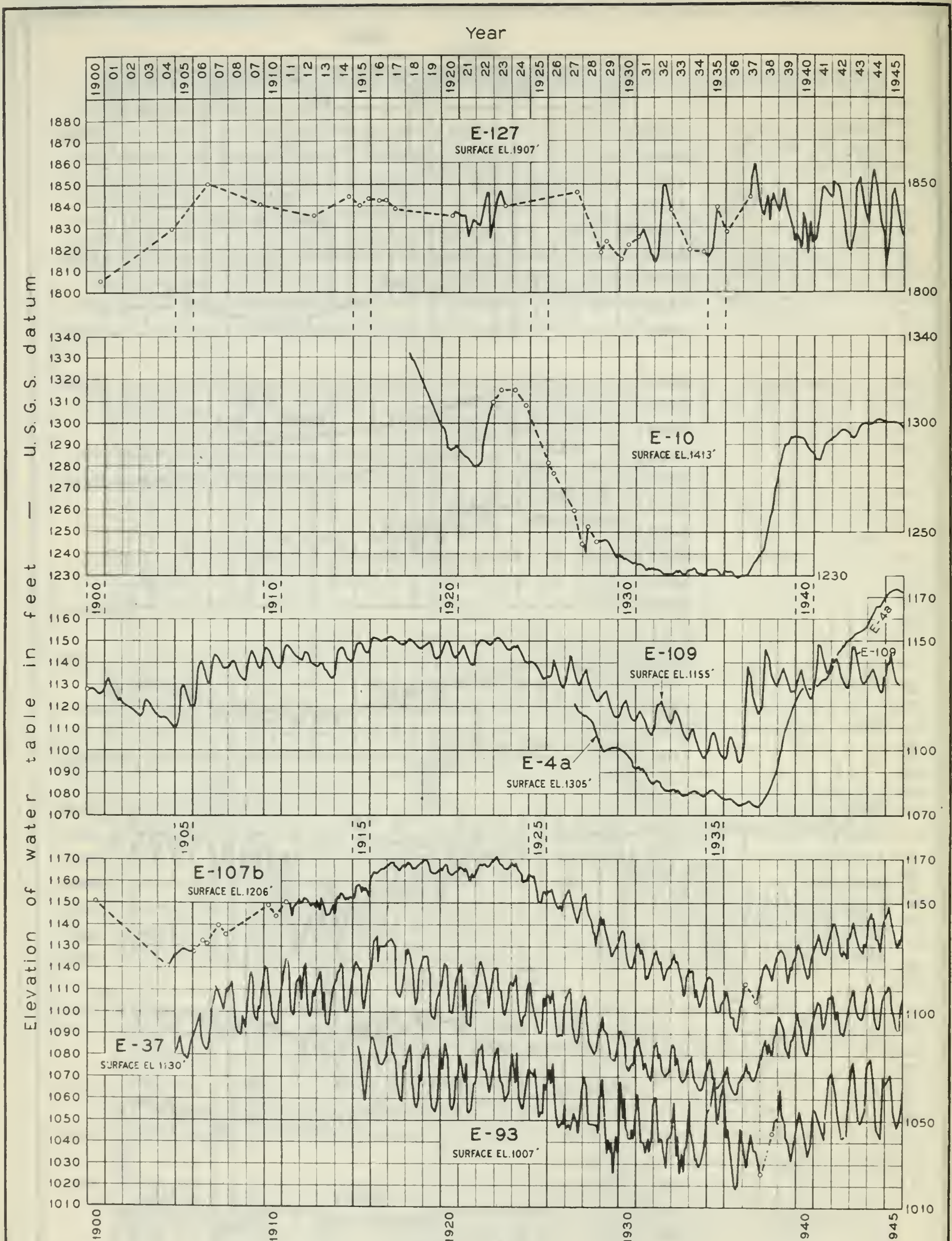
FLUCTUATION OF WATER TABLE AT WELLS
LYTLE, CUCAMONGA, RIALTO & CHINO BASINS



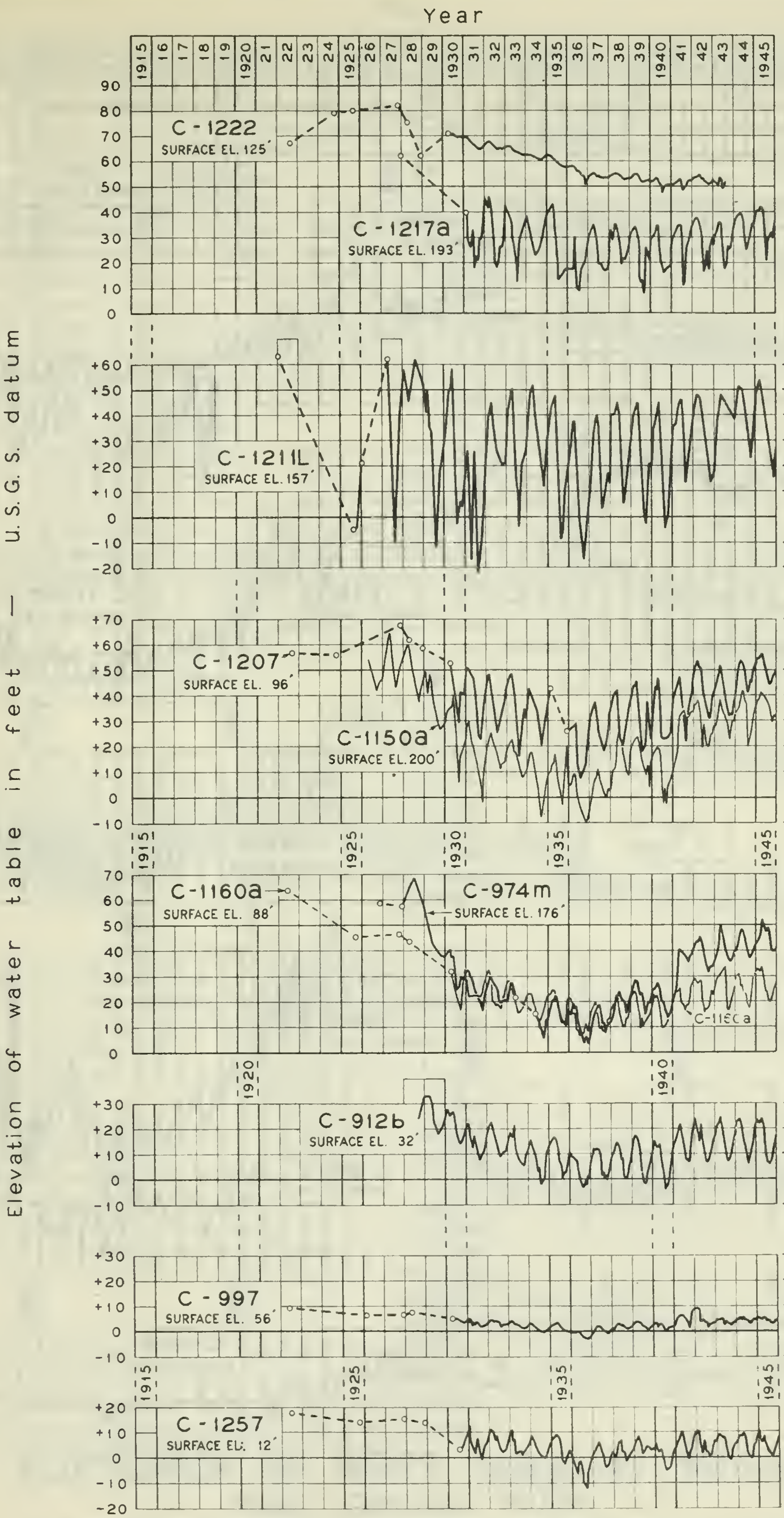
FLUCTUATION OF WATER TABLE AT WELLS

BEAUMONT, YUCAIPA, SAN TIMOTEO, RIVERSIDE, TEMESCAL AND ARLINGTON BASINS

PLATE 16

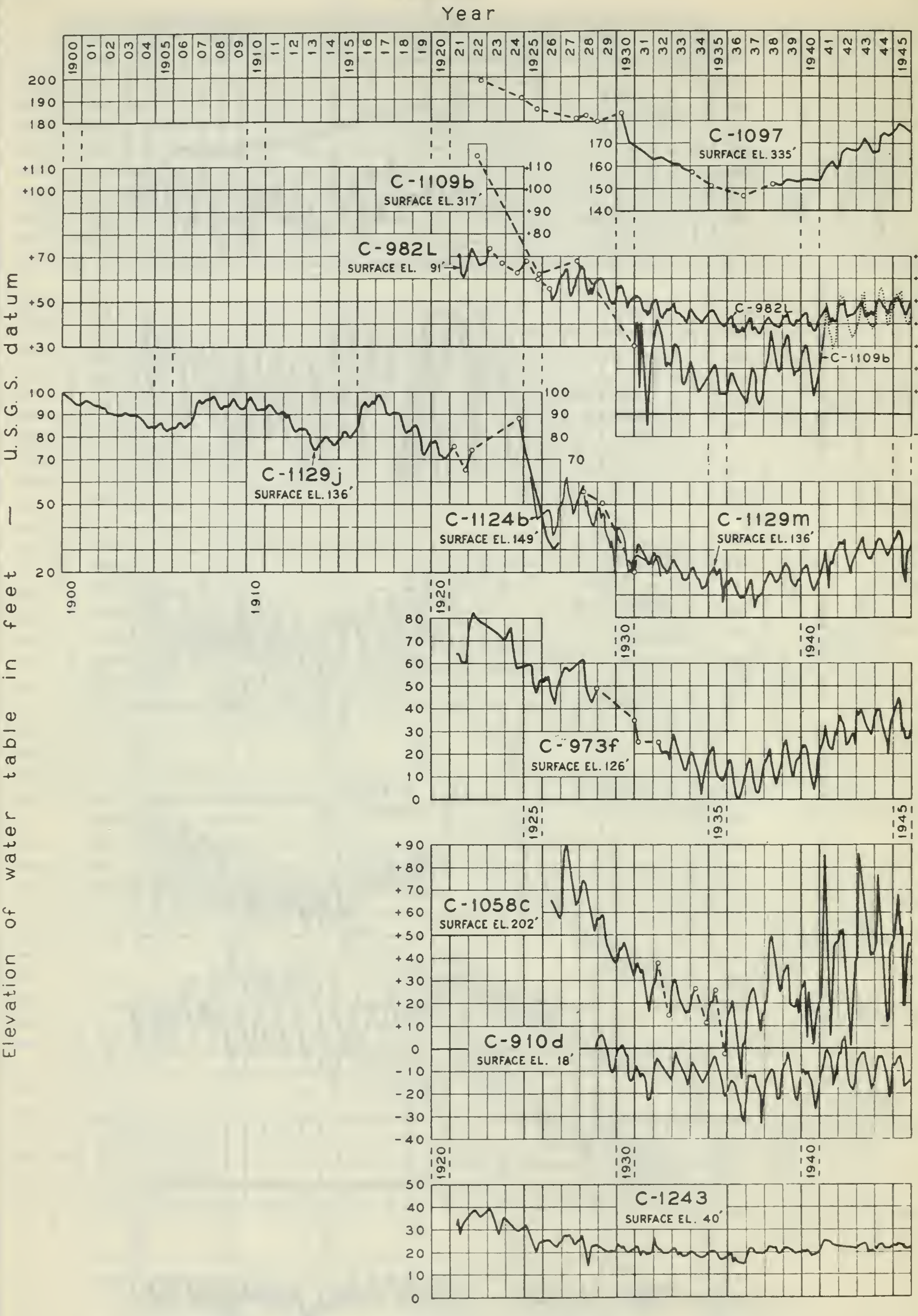


FLUCTUATION OF WATER TABLE AT WELLS
BUNKER HILL AND DEVIL CANYON BASINS

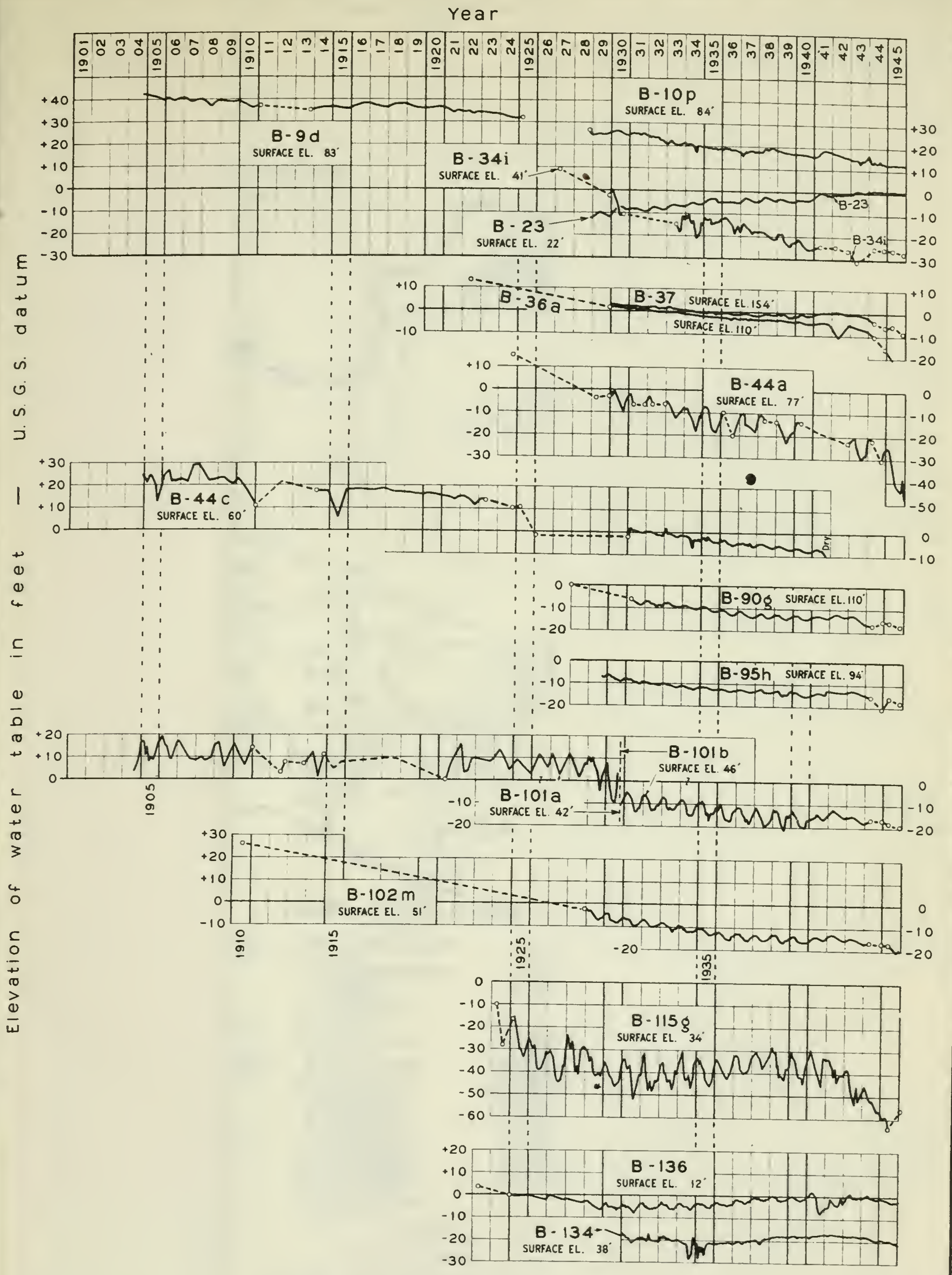


FLUCTUATION OF WATER TABLE AT WELLS
EAST COASTAL PLAIN

PLATE 18

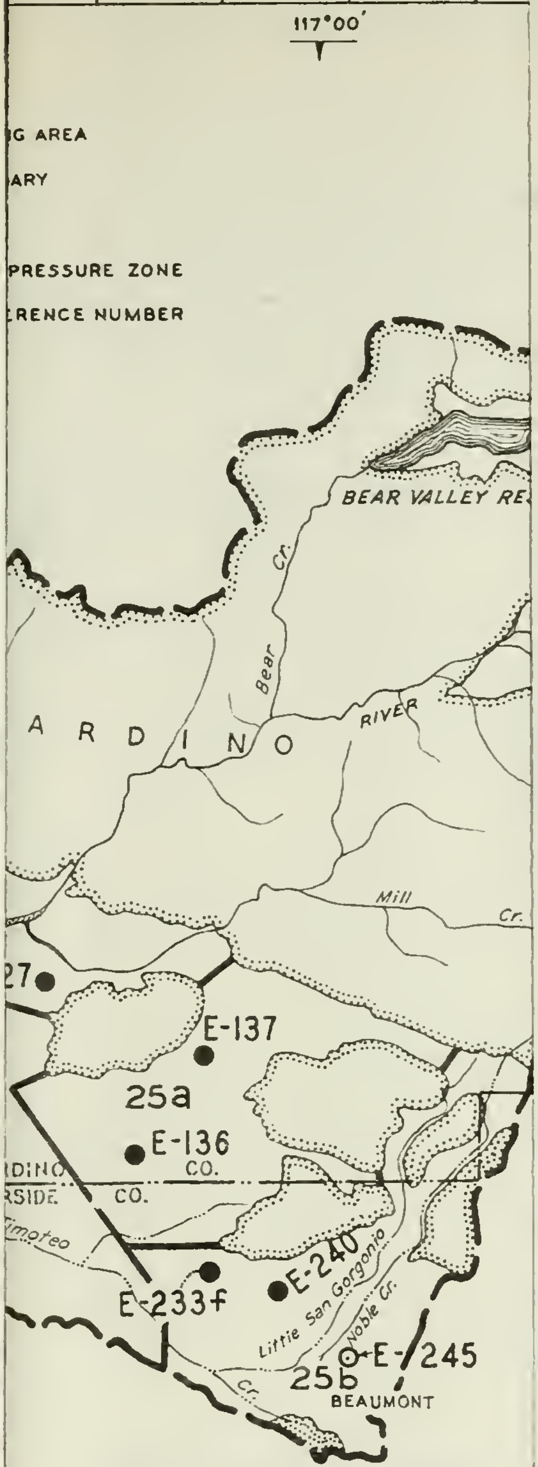


FLUCTUATION OF WATER TABLE AT WELLS
EAST COASTAL PLAIN



FLUCTUATION OF WATER TABLE AT WELLS
WEST COASTAL PLAIN

31	32	33	34	3



GROUND WATER BASINS

VALLEY	UPPER SANTA ANA VALLEY	
O	16 CHINO	47 LEE
	17 CLAREMONT HEIGHTS	48 COL
	18 LIVE OAK	49 BEDF
	19 POMONA	
	20 CUCAMONGA	
	21a RIALTO	
NGA	21b COLTON	31a WES
	22 BUNKER HILL	31b WES
LLEY	23 LYTLE	32 HOLL
	24 DEVIL CANYON	33a LOS
RIEL	25a YUCAIPA	33b MON
	25b BEAUMONT	33c SAN
	26 SAN TIMOTEO	33d IRVI
	27 RIVERSIDE	33e CEN
N	28 ARLINGTON	33f EAST
N	29 TEMESCAL	34 LA H
	40 LOWER CAJON	35 YORB
	41 UPPER CAJON	36 LOS
	42 BEAR VALLEY	37 SAN
	43 BIG MEADOWS	50 SAN
	44 SEVEN OAKS	
	45 RECHE CANYON	
	46 CAJALCO	

117°00′

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCE
UTH COASTAL BASIN INVESTI

ION OF WELLS A
LE FLUCTUATION

5 10
25,000 50,000

31	32	33	34	35

CHAPTER V. DISCUSSION OF ITEMS INVOLVED IN EVALUATION OF OVERDRAFT

CHANGE IN STORAGE

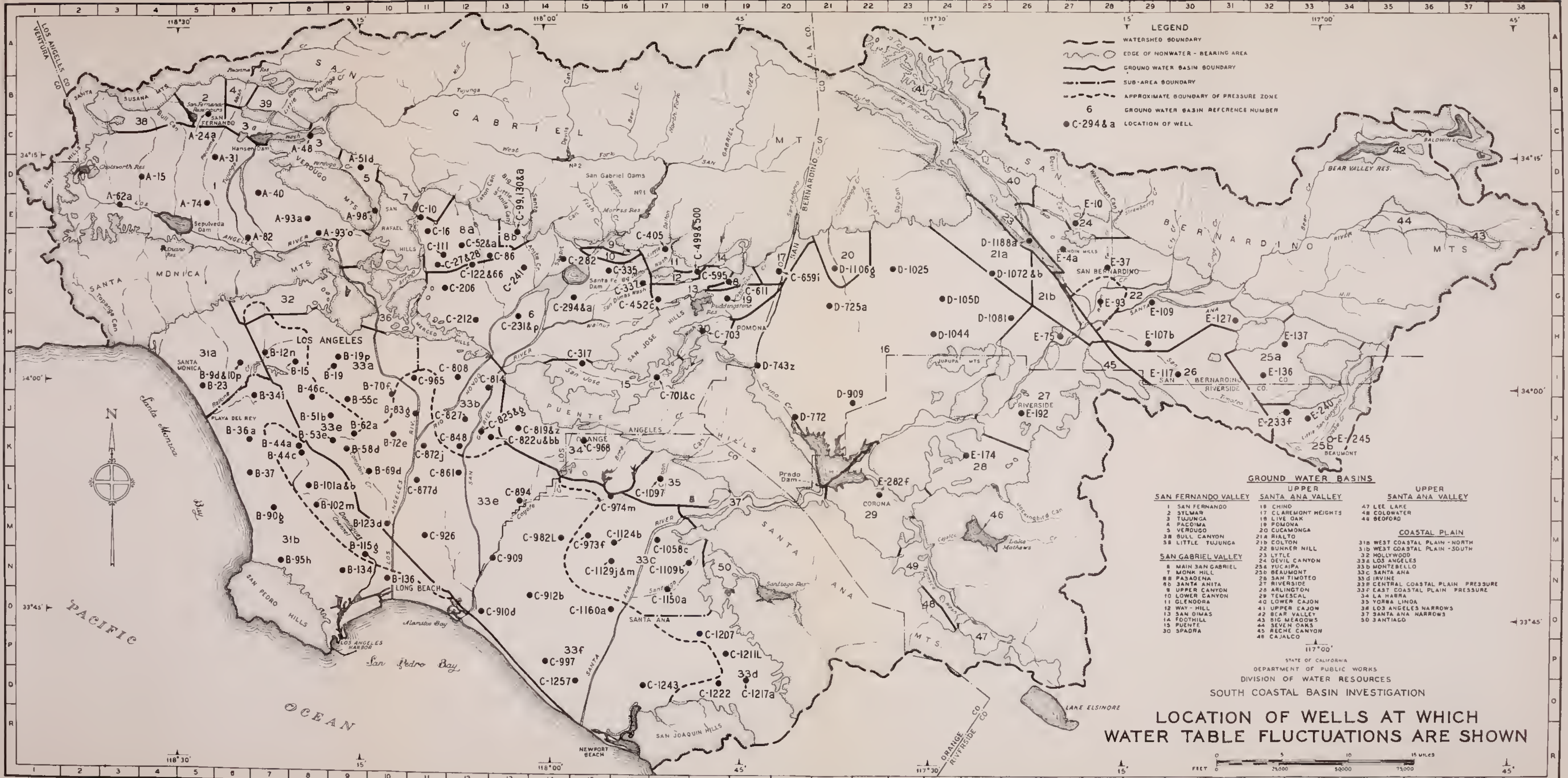
All soil from ground surface to bed-rock contains some water at all times. Below the water table all pore space is occupied by water; above it a large part is occupied by air, but a film of water surrounds each solid particle. The amount of water, both below and above the water table, varies widely from time to time. These variations represent changes in storage.

Since all pore space below the water table is occupied by water at all times, variation there is by vertical movement of the water table itself. When the water table rises, air is displaced by water; when it falls only the film is retained, and air displaces the remainder. The change in storage below the water table, during any period of time, occurs in the mass of alluvium lying between its position at the beginning and at the end of the period.

Just how much water this change represents depends upon the volume occupied by air when the water table is low, and by water when it is high. Two things determine this volume: first, the total pore space; and second, the volume already occupied by water prior to a rise, or which is retained there during and following a drop. Total pore space is a function of the grading of materials making up the alluvium. The amount of water retained is a function of both total surface area of the solid particles, and thickness of the film covering this surface. Both are greater where the material is finer. Thus, in coarse, poorly assorted materials, both total pore space and retention are relatively small, while in fine materials of more uniform shape and size both are larger.

During the investigation reported in Bulletin 45, it was found that total pore space in unweathered gravels increases more rapidly with distance from the apex of an alluvial cone at the base of the mountains than does specific retention, so specific yield, i.e., the amount of water which can be put into or extracted from a unit volume of unweathered gravels, increases generally with distance from the mountains. This holds true up to the distance where the material is mostly coarse sand. As the material becomes still finer, however, specific retention increases more rapidly, and yield is again reduced.

Weathering, which has acted to a varying degree on a large part of the materials which make up the valley fill, has changed total pore space little, but has reduced the size of individual particles, and so increased retention. Yield is thus reduced to a degree depending upon the stage of weathering. Where the fresh materials were poorly assorted, and virtually complete weathering has produced clay, yield is almost negligible, being even smaller than that from silts almost equally fine which were deposited under conditions such that total pore space is larger.


LEGEND
WATERSHED BOUNDARY
EDGE OF NONWATER - BEARING AREA
GROUND WATER BASIN BOUNDARY
SUB-AREA BOUNDARY
APPROXIMATE BOUNDARY OF PRESSURE ZONE
6 GROUND WATER BASIN REFERENCE NUMBER
C-294 & a LOCATION OF WELL
GROUND WATER BASINS
SAN FERNANDO VALLEY
1 SAN FERNANDO
2 SYLMAR
3 TUJUNGA
4 PACOIMA
5 VERDUGO
38 BULL CANYON
39 LITTLE TUJUNGA
SAN GABRIEL VALLEY
6 MAIN SAN GABRIEL
7 MONK HILL
8a PASADENA
8b SANTA ANITA
9 UPPER CANYON
10 LOWER CANYON
11 GLENDORA
12 WAY - HILL
13 SAN DIMAS
14 FOOTHILL
15 PUENTE
30 SPADRA
UPPER SANTA ANA VALLEY
16 CHINO
17 CLAREMONT HEIGHTS
18 LIVE OAK
19 POMONA
20 CUCAMONGA
21a RIALTO
21b COLTON
22 BUNKER HILL
23 LYTLE
24 DEVIL CANYON
25a YUCAIPA
25b BEAUMONT
26 SAN TIMOTEO
27 RIVERSIDE
28 ARLINGTON
29 TEMESCAL
40 LOWER CAJON
41 UPPER CAJON
42 BEAR VALLEY
43 BIG MEADOWS
44 SEVEN OAKS
45 RECHE CANYON
46 CAJALCO
UPPER SANTA ANA VALLEY
47 LEE LAKE
48 COLDWATER
49 BEDFORD
COASTAL PLAIN
31a WEST COASTAL PLAIN - NORTH
31b WEST COASTAL PLAIN - SOUTH
32 HOLLYWOOD
33a LOS ANGELES
33b MONTEBELLO
33c SANTA ANA
33d IRVINE
33e CENTRAL COASTAL PLAIN PRESSURE
33f EAST COASTAL PLAIN PRESSURE
34 LA HABRA
35 YORBA LINDA
36 LOS ANGELES NARROWS
37 SANTA ANA NARROWS
50 SANTIAGO
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SOUTH COASTAL BASIN INVESTIGATION
LOCATION OF WELLS AT WHICH
WATER TABLE FLUCTUATIONS ARE SHOWN
PACIFIC
OCEAN
Santa Monica Bay
San Pedro Bay
LOS ANGELES
LONG BEACH
SANTA ANA
POMONA
SAN BERNARDINO
RIVERSIDE
CORONA
BEAUMONT
NEWPORT BEACH
SAN GABRIEL MTS
SAN BERNARDINO MTS
SANTA MONICA MTS
SANTA ANA MTS
SAN JOAQUIN HILLS
SAN PEDRO HILLS
LAKE ELSINORE
Lake Mathews
BEAR VALLEY RES.
Prado Dam
Hansen Dam
Sepulveda Dam
Santa Fe Dam
San Gabriel Dams

CHAPTER V. DISCUSSION OF ITEMS INVOLVED IN EVALUATION OF OVERDRAFT

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Weathering, which has acted to a varying degree on a large part of the materials which make up the valley fill, has changed total pore space little, but has reduced the size of individual particles, and so increased retention. Yield is thus reduced to a degree depending upon the stage of weathering. Where the fresh materials were poorly assorted, and virtually complete weathering has produced clay, yield is almost negligible, being even smaller than that from silts almost equally fine which were deposited under conditions such that total pore space is larger.

As stated, storage changes also occur between the highest position of the water table and the ground surface. At the surface, and in the root zone, just below, thickness of film of water surrounding each soil particle varies widely from time to time. After a protracted dry period, that near the surface may be so reduced that only hygroscopic moisture, i.e., that which adheres so closely to the soil particles that it can be removed only by the application of heat, remains. Deeper in the root zone, extractions by vegetation and by aeration may reduce it almost but not quite to that extent. On the other hand, following application of sufficient water, the film throughout the zone is, at least temporarily, thick enough so that part of the water moves downward under the force of gravity. Between root zone and water table the minimum thickness of the film is greater, because none is extracted by plants, evaporation is negligible, and only gravity acts to reduce it. While the greater part of the removable water drains out quickly, there is generally a small long-continued downward movement in this zone. Where depth from ground surface to water table is great, variations in the amount of this water in transit from the surface to the water table may be material. In certain areas, too, percolating water meets with obstructions to its downward movement, in which case a localized perched water table may result, and the movement may become nearly horizontal until the water reaches a point where it can again move downward. In extreme cases, total changes in storage above the water table are great enough to completely regulate a widely varying input, so that the supply as it reaches the water table is almost uniform.

Because a reliable estimate of the amount of this change above the water table is virtually impossible, total changes in storage below the ground surface can be determined best for those periods in which the amount in storage above the water table is about the same at beginning and end of the periods. In the 11-year period, 1927-28 to 1937-38, inclusive, this condition should have been approximately true, because it was preceded by and ended with two wet years.

The method employed in this bulletin to estimate change in storage between two positions of the water table was developed in Division of Water Resources Bulletin 45, ''Geology and Ground Water Storage Capacity of Valley Fill,'' and is discussed in detail in that bulletin. Briefly, the method involves five steps:

(1) Specific yield of unweathered gravels at all points in the area is estimated on the basis of laboratory determinations and geologic considerations.

(2) Specific yield of alluvium in various stages of weathering at all points in the area is estimated, using the values of step (1) as a basis.

(3) Average specific yield of alluvium throughout the depth penetrated by each of several groups of wells, distributed over the area, is determined from step (2), and drillers' logs of the wells. By applying this average value at the center of the group, a map is drawn showing lines of equal specific yield.

(4) From water level measurements at wells, a map showing lines of equal change in elevation of the water table is drawn.

(5) Change in storage in acre-feet is obtained for each of several small areas by multiplying average change in feet depth (step 4), by

average specific yield (step 3), and multiplying the result by the area in acres. The total for the basin is obtained by adding together the values for these increments of area.

Results, so obtained, are presented in Table 5. In deriving the values, an arbitrary allowance has been made for storage changes in the large pressure areas of Central and East Coastal Plains. While piezometric changes in the pressure area cannot be used as in step (5), above, recent studies indicate that some change in storage does accompany change in pressure.

PRECIPITATION

Values of precipitation on basins, or groups of basins where they are combined for reasons stated in Chapter VI, derived as described below, are presented in Table 7. The derivation of 53-year mean precipitation at all stations is discussed in Chapter III. The location of lines of equal precipitation shown on Plate 21 are interpolated between the stations. From this map, 53-year mean annual precipitation on the various subdivisions is estimated. Average annual precipitation for shorter periods is estimated by applying the ratio between shorter period and 53-year mean annual precipitation for the applicable group of stations, as shown in Table 6.

TABLE 6. RATIOS BETWEEN SHORTER PERIOD AVERAGE ANNUAL AND 53-YEAR MEAN ANNUAL PRECIPITATION

Group	*32-year period, 1904-05 to 1935-36, inclusive*	*29-year period, 1904-05 to 1932-33, inclusive*	*21-year period, 1922-23 to 1942-43, inclusive*	*11-year period, 1927-28 to 1937-38, inclusive*
San Fernando	1.041	1.044	1.076	1.022
San Gabriel	0.970	0.970	0.970	0.949
Raymond Basin:				
Valley	---	1.013	1.034	1.000
Mountain	---	1.013	1.004	1.000
Chino	0.974	0.985	0.964	0.939
Bear Valley	0.944	0.956	0.912	0.921
San Bernardino	1.042	1.057	1.051	1.034
Riverside	1.030	1.047	1.082	1.072
Coastal Plain	0.964	0.969	1.012	0.982

TABLE 7. ESTIMATED AVERAGE ANNUAL PRECIPITATION ON BASINS

During

53-Year Period, 1883-84 to 1935-36, Inclusive
32-Year Period, 1904-05 to 1935-36, Inclusive
29-Year Period, 1904-05 to 1932-33, Inclusive
21-Year Period, 1922-23 to 1942-43, Inclusive
11-Year Period, 1927-28 to 1937-38, Inclusive

(Acre-feet)

Basin name and number	*53-year period*	*29-and 32-year periods*	*21-year period*	*11-year period*
Verdugo Basin (5)	8,380	8,750[b]	9,020	8,570
San Fernando Valley Area[a] (1, 2, 3, 4, 38 and 39)	171,680	179,230[b]	184,720	175,450
Raymond Basin Area				
Western Unit[a] (7 and 8a)	40,820	41,350[b]	42,210	40,810
Eastern Unit (8b)	4,310	4,370[b]	4,460	4,310
Glendora Basin (11)	6,080	5,900[b]	5,900	5,770
Way Hill Basin (12)	2,880	2,800[b]	2,800	2,730
Foothill Basin (14)	2,240	2,180[b]	2,180	2,130
San Dimas Basin (13)	8,040	7,800[b]	7,800	7,630
Spadra Basin (30)	6,460	6,270[b]	6,270	6,130
Puente Basin (15)	19,540	18,950[b]	18,950	18,540
Central San Gabriel Valley Area[a] (6, 9 and 10)	122,090	118,430[b]	118,430	115,860
La Habra Basin (34)	32,570	31,560[b]	32,960	31,890
Lower Los Angeles and San Gabriel Rivers area—Nonpressure[a] (32, 33a, 33b and 36)	97,340	94,320[b]	98,500	95,580
Claremont Heights Basin (17)	9,740	9,490	9,390	9,150
Live Oak Basin (18)	3,390	3,280	3,280	3,210
Pomona Basin (19)	8,930	8,660	8,660	8,480
Cucamonga Basin (20)	16,460	16,030	15,870	15,460
Rialto Basin (21a)	23,790	24,790	25,010	24,600
Lower Cajon Basin (40)	10,640	11,090	11,190	11,000
Lytle Basin (23)	6,910	7,200	7,260	7,140
Devil Canyon Basin (24)	11,420	11,890	12,000	11,800
Yucaipa Basin (25a)	27,550	28,700	28,950	28,480
Beaumont Basin (25b)	33,230	34,620	34,920	34,360
San Timoteo Basin (26)	35,170	36,440[c]	37,490[c]	37,030[c]
Bunker Hill Basin (22)	83,340	86,850	87,600	86,180
Colton-Reche Canyon Area[a] (21b and 45)	15,310	15,900	16,230	16,000
Riverside-Arlington Area[a] (27 and 28)	46,080	47,470	49,860	49,400
Temescal Basin (29)	20,110	20,720	21,760	21,560
Chino Basin (16)	209,350	208,490[c]	210,150[c]	205,960[c]
Irvine Basin (33d)	34,780	33,530	35,200	34,160
Lower Santa Ana River Area—Nonpressure[a] (33c, 35, 37 and 50)	88,400	85,220	89,460	86,800

[a] Basins grouped for reasons stated in Chapter VI.
[b] 29-year period used for these basins, 32-year period for remainder.
[c] Weighted ratios of values from concerned groups of rainfall stations used.

MOUNTAIN AND HILL RUNOFF

Records of runoff from 1904-05* to date at one point on each of three streams, San Gabriel River, Santa Ana River and San Antonio Creek, are available. From these records alone, average runoff during the 32-year, 29-year, 21-year and 11-year periods can be determined for a considerable portion of the mountain area. Records covering the 11- and 21-year periods are available at one or more points on many other streams. While these shorter records do not cover all of the 29- or 32-year periods, average discharge for those periods can be estimated by comparison with one of the three long record stations. These estimates, next in order of reliability to actual measurements, evaluate runoff from the greater part of remaining mountain area.

Runoff from most hill land, and from a small area of mountains adjacent to the valley, which has not been measured, is estimated from precipitation. Runoff from this area can be divided into two parts: that which flows off either so rapidly, or through such channels that it is not available to vegetation; and that which drains more slowly through the root zone, and is the residue after requirements of plants have been met. Where precipitation is heavy, the density and extent of vegetation depends upon the character of the terrain and its soil cover. In this case, total runoff is determined by consumptive use. Where precipitation is light, the type and density of vegetation is limited by water available to it. Virtually all water which does not evaporate or run off immediately is held in the soil cover and later consumed. Runoff in such cases is a function of precipitation rather than of consumptive use.

The foregoing considerations, and measured and estimated runoff at gaging stations shown, provide the basis for the diagrams of Plate 22, which are used as a guide to judgment in estimating long-time mean runoff from mountain and hill areas for which no measurements are available. These comprise about 23 percent of total mountain, and 80 percent of total hill area. Shorter period runoff from the mountains is assumed to be proportional to that in one of the long record streams, that from the hills proportional to precipitation.

The procedure followed in deriving values for surface inflow from directly tributary mountains and hills to each subdivision of the area, together with both surface and subsurface inflow from other subdivisions of valley areas, is described in Chapter VI. There the historic 11-year average annual values, and estimates of 21- and 29- or 32-year mean annual values under present conditions are presented. In Table 8, only the estimated long-time mean annual inflow under present conditions, and the 11-year base period average annual historic inflow used in deriving the values presented in Tables 5 and 12 are shown. Except where noted, the 21-year value is considered to be the long-time mean.

* Earlier records are available but are not required for this purpose.

TABLE 8. ESTIMATED AVERAGE ANNUAL INFLOW TO BASINS
(Acre-feet)

Basin name and number	Surface: Long-time mean	Surface: 11-year base period average	Subsurface[a]: Long-time mean	Subsurface[a]: 11-year base period average
Verdugo Basin (5)	2,630	2,470	0	0
San Fernando Valley Area[b] (1, 2, 3, 4, 38 and 39)	40,650	35,130	0	450
Raymond Basin Area				
Western Unit[b] (7 and 8a)	13,170	11,650	0	0
Eastern Unit (8b)	6,410	5,780	0	0
Glendora Basin (11)	2,550	2,280	0	0
Way Hill Basin (12)	610	400	0	0
Foothill Basin (14)	3,660	3,190	0	0
San Dimas Basin (13)	3,000	2,780	1,080	1,080
Spadra Basin (30)	940	920	710	710
Puente Basin (15)	3,830	3,750	1,150	1,150
Central San Gabriel Valley Area[b] (6, 9 and 10)	131,370	122,600	13,800	13,800
La Habra Basin (34)	2,700[c]	2,680	0	0
Lower Los Angeles and San Gabriel Rivers Area — Nonpressure[b] (32, 33a, 33b and 36)	141,130	123,360	36,010	36,010
Claremont Heights Basin (17)	23,260	22,260	0	0
Live Oak Basin (18)	370	310	3,320	3,320
Pomona Basin (19)	390	360	4,390	4,390
Cucamonga Basin (20)	7,870	7,450	0	0
Rialto Basin (21a)	35,190	33,730	0	0
Lower Cajon Basin (40)	15,230	15,150	0	0
Lytle Basin (23)	11,340	12,100	0	0
Devil Canyon Basin (24)	11,400	10,590	0	0
Yucaipa Basin (25a)	5,270	5,200	0	0
Beaumont Basin (25b)	5,750	5,650	0	0
San Timoteo Basin (26)	2,280[d]	2,170	6,720	6,720
Bunker Hill Basin (22)	114,670	113,510	31,790	34,420
Colton-Reche Canyon Area[b] (21b and 45)	36,220	35,810	20,110	20,110
Riverside-Arlington Area[b] (27 and 28)	31,420	29,770	20,110	20,110
Temescal Basin (29)	8,690	7,400	3,000	3,000
Chino Basin (16)	72,760	68,490	25,490	22,660
Irvine Basin (33d)	3,880	3,770	0	0
Lower Santa Ana River Area—Nonpressure[b] (33c, 35, 37 and 50)	110,280	102,860	2,400	2,400

[a] Subsurface inflow from mountains and hills included with surface inflow.
[b] Basins grouped for reasons stated in Chapter VI.
[c] Average of 29- and 21-year mean annual values.
[d] 32-year mean annual value.

IMPORT

Water is imported in varying amounts to most basins, and sewage from other basins is used for irrigation in a few. A part of the imported water originates outside South Coastal Basin in Owens Valley and Mono Basin, Colorado River and San Jacinto Valley. Water from Colorado River, and sewage, the identity of which is maintained until its final destination is reached, are considered imports only to basins in which they are used, or commingled with other waters. Import of other water to each basin is the total entering from immediately adjacent basins, no matter where it originates.

The values for each year since 1927-28, presented in Chapter VI, are based primarily on measurements, and origin of the water has little bearing on the evaluation of historic 11-year average annual imports. The origin does, however, largely influence the relationship between historic and mean annual values under present conditions. The amount imported in any year from gravity sources, either mountain streams, rising water or sewage, is determined primarily by the amount available; that originating in pumping from ground water depends more upon the demand which must be satisfied from this more expensive water. This demand fluctuates with the weather, and with the amount of cheaper water available, and in some cases has also shown marked progressive increase with recent cultural development. The discussion of present import to each basin, in Chapter VI, includes in each case a statement of the records used in the estimate. The values there derived, and the 11-year average values, including both water and sewage, are presented in Table 9. There is no import to those basins not included in the table.

TABLE 9. AVERAGE ANNUAL IMPORT TO BASINS

(Acre-feet)

Basin name and number	*Under present conditions, estimated*	*Historic during 11-year base period*
San Fernando Valley Area [a] (1, 2, 3, 4, 38 and 39)	308,760 [b]	209,690
Western Unit of Raymond Basin Area [a] (7 and 8a)	5,910 [c]	3,480
Glendora Basin (11)	2,760	2,910
Way Hill Basin (12)	1,540	1,200
Foothill Basin (14)	160	120
San Dimas Basin (13)	5,250	3,500
Spadra Basin (30)	1,800	1,370
Puente Basin (15)	5,640 [d]	4,020 [d]
Central San Gabriel Valley Area [a] (6, 9 and 10)	15,780 [d]	18,250 [d]
La Habra Basin (34)	18,830	18,400
Lower Los Angeles and San Gabriel Rivers Area—nonpressure [a] (32, 33a, 33b and 36)	214,930	140,310
Claremont Heights Basin (17)	80	100
Live Oak Basin (18)	2,030	1,810
Pomona Basin (19)	4,600	3,930
Cucamonga Basin (20)	4,340	3,840
Rialto Basin (21a)	5,720	4,930
Lytle Basin (23)	10,620	10,520
San Timoteo Basin (26)	18,150	20,300
Bunker Hill Basin (22)	8,490	3,580
Colton-Reche Canyon Area [a] (21b and 45)	70,960 [d]	62,820 [d]
Riverside-Arlington Area [a] (27 and 28)	71,500 [d]	65,330 [d]
Temescal Basin (29)	15,420	14,550
Chino Basin (16)	42,040	39,150
Irvine Basin (33d)	9,440	7,300
Lower Santa Ana River Area—nonpressure [a] (33c, 35, 37 and 50)	4,680	1,320

[a] Basins grouped for reasons stated in Chapter VI.
[b] Includes water available to Los Angeles Aqueduct in Mono Basin and Owens Valley. See discussion of excess in San Fernando Valley Area in Chapter VI.
[c] Amount required to prevent overdraft, calculated by solving hydrologic equation.
[d] Includes sewage.

CONSUMPTIVE USE

As implied by the term itself, consumptive use is a measure of water actually used up.

In most industrial processes a very small part of the applied water goes into the product; in some a large part of the remainder is evaporated; in others the greater part, after serving its purposes in the factory, is discharged as waste, either into sewers, drains or cesspools. Only that part of the applied water which remains in the product, or is evaporated, is actually consumed. That which goes into cesspools returns to the ground water and becomes a part of it; that discharged into drains and sewers may be available for re-use at any time before it reaches the ocean. Any of this discharged water which is not actually returned to the ground water, or otherwise held available for re-use within the basin, is considered either as a part of the surface outflow, or separately as sewage. Even though it has served a useful purpose, neither the return flow nor the outflow is a part of the consumptive use. Of precipitation which falls on roofs and other impervious surfaces, only the relatively small part which is evaporated is consumed. The remainder either flows off onto more absorptive areas, and in part percolates there, or follows impervious channels and becomes a part of the surface outflow. Generally speaking, consumptive use from areas devoted solely to industry is not very large, and since a separate determination of its amount would involve more work than seems justified, industrial areas are in most cases here treated as a part of the general municipal development.

On areas occupied by natural vegetation, or devoted to agricultural crops, or to the lawns, ornamental shrubbery and trees which are an important part of urban development, it is equally true that a considerable part of the applied water and precipitation either runs off, or penetrates below the root zone and eventually becomes a part of the ground water. Only that part which is evaporated from the surface, transpired by plants, or remains in the growing vegetation is actually consumed. Of this, the larger part is evaporated or transpired.

The type of natural vegetation which develops on an area is largely dependent upon the amount of water available. In swampy areas the supply is unlimited, and consumptive use is large. Elsewhere, native vegetation ranges from grass and weeds in areas of light rainfall, to deeper rooted brush where precipitation is greater. While some water doubtless passes below the root zone in years when precipitation is grossly in excess of average, consumptive use by native vegetation is greater in wetter years, as evidenced by more luxuriant growth, and it is probable that its average value over a long period of time is only a little less than the mean precipitation. In those areas where the water table is not close enough to the surface to support swamp vegetation, but is still high enough so that capillary water occupies a large part of the root zone, perennial grasses and weeds may develop. Since they continue to grow and use water for a much greater part of the year than do those dependent entirely upon rainfall, it is possible for consumptive use by native vegetation in such areas to materially exceed mean precipitation.

Few irrigated crops produced in South Coastal Basin are native, and the water requirement of each is fixed more by the nature of the plant itself than by its environment. Many crops are shallow-rooted, so that only a limited amount of precipitation can be stored in the root zone for later consumption. In the case of deeper rooted plants, stored precipitation reduces the amount of applied water required, but has little if any effect on the total amount consumed. Thus, with irrigated culture there is no correlation between precipitation and consumptive use. Elevation of the ground water, too, generally has little influence on the amount consumed by irrigated vegetation. In the case of most crops the water table must remain below the root zone, and where the soil in that zone is kept moist by irrigation, the effect of capillarity is limited. Both irrigated grass and alfalfa, however, use more water when more is available, so it is probable that elevation of the water table, where it is near the ground surface, does affect the amount consumed by those crops.

Temperature and humidity have a bearing on the amount consumed by both natural and irrigated vegetation. Consumption is generally greater in inland valleys than nearer the ocean, where temperature during the growing season is lower and the atmosphere not so dry. For the same reason it varies from one inland point to another.

In Chapter VI values of historic 11-year and present average annual consumptive use are derived for each subdivision of the area. The unit values used are consistent with the foregoing considerations, and with experimental research. However, the values are finally established as those which result in reasonable values of subsurface outflow, when the hydrologic equation is applied to areas above points where a measure of the reasonableness exists. Derived subsurface outflow at Los Angeles and Whittier Narrows, and from Chino into Spadra Basin, control unit consumptive use values assigned in the three island valleys. In Chapter VI reasons for acceptance of the derived values are briefly discussed in connection with subsurface outflow from San Fernando Valley Area, Central San Gabriel Valley Area and Chino Basin. It is there shown that change in unit values of consumptive use has far greater effect upon derived subsurface outflow than upon estimated excess or overdraft. Within each valley the unit values are varied in accordance with the other considerations mentioned but must still be such that the derived subsurface flow is in the direction required by the slope of the ground water. On the Coastal Plain values which are consistent with those used inland are assigned.

Deep percolation, runoff and consumptive use on unirrigated lands are all greater in wet than in dry years. In recognition of this variation, unit values assigned to unirrigated culture are different in the three periods for which consumptive use is evaluated. It is assumed that half the additional rain in the wetter period is consumed. Long-time mean values presented in Table 10 are, except where noted, based on the 21-year period.

Tributary to some basins there are considerable areas of occupied or cultivated hill and mountain lands supplied with water from the valleys, or with water which would form a part of valley supply if not diverted to use before reaching it. Only that part of the precipitation on hills and mountains which runs off forms a part of the usable supply, and, in the estimate of that supply, consumptive use by native vegetation on hills and mountains has already been subtracted. Unit consumptive use by the various crops in the valleys includes that from rainfall, so unit values for hills and mountains are the differences between those for the same crops in the valleys and the precipitation which would have been consumed on hills and mountains had the same area been occupied by native vegetation.

In estimating consumptive use values, derived in Chapter VI and presented in Table 10, acreages of various crops and types of culture, as determined by surveys carried on by the Division of Water Resources* in 1932 and 1942, are used, it being assumed generally* that average conditions during the 11-year base period are represented by the former survey and present conditions by the latter. The principal change in culture since 1942 has been in domestic and industrial development, for which unit consumptive use is generally not greatly in excess of that for unirrigated lands and is less than that for most irrigated crops. Present consumptive use is in most cases probably little, if any, greater than it was in 1942.

TABLE 10. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN BASINS

(Acre-feet)

Basin name and number	*Under present conditions, estimated*	*Historic during 11-year base period*
Verdugo Basin (5)	7,530	7,440
San Fernando Valley Area[a] (1, 2, 3, 4, 38 and 39)	232,230	227,540
Raymond Basin Area		
Western Unit[a] (7 and 8a)	36,170	36,170
Eastern Unit (8b)	3,910	3,910
Glendora Basin (11)	6,100	6,100
Way Hill Basin (12)	2,890	2,870
Foothill Basin (14)	2,020	1,980
San Dimas Basin (13)	8,890	8,880
Spadra Basin (30)	7,650	7,410
Puente Basin (15)	21,940	21,330
Central San Gabriel Valley Area[a] (6, 9 and 10)	126,800	125,940
La Habra Basin (34)	42,580[b]	42,670
Lower Los Angeles and San Gabriel Rivers Area—Nonpressure[a c] (32, 33a, 33b and 36)	90,620	90.320
Claremont Heights Basin (17)	9,250	9,100
Live Oak Basin (18)	3,790	3,780
Pomona Basin (19)	9,650	9,630
Cucamonga Basin (20)	15,710	15,130
Rialto Basin (21a)	24,930	24,740
Lower Cajon Basin (40)	7,820	7,760
Lytle Basin (23)	6,810	6,830
Devil Canyon Basin (24)	10,970	10,980
Yucaipa Basin (25a)	29,710	30,370
Beaumont Basin (25b)	33,380	33,290
San Timoteo Basin (26)	43,790[c]	43,720
Bunker Hill Basin (22)	110,830	109,370
Colton-Reche Canyon Area[a] (21b and 45)	20,370	20,160
Riverside-Arlington Area[a] (27 and 28)	98,520	96,960
Temescal Basin (29)	34,050	32,760
Chino Basin (16)	273,740	270,460
Irvine Basin (33d)	39,990	37,330
Lower Santa Ana River Area—Nonpressure[a] (33c, 35, 37 and 50)	120,920	119,970

[a] Basins grouped for reasons stated in Chapter VI.
[b] Average of 29- and 21-year mean annual values.
[c] 32-year mean annual value.

* Exceptions are noted in Chapter VI.

EXPORT

Export values presented in Table 11 include both water and sewage. The water may originate in imports, in diversions from mountain streams tributary to the basins, in rising water near their lower boundaries, or in wells within the basins. The general principles involved have been discussed in connection with import, and the assumptions upon which the export values for each basin are based are stated in Chapter VI.

TABLE 11. AVERAGE ANNUAL EXPORT FROM BASINS

(Acre-feet)

Basin name and number	*Under present conditions, estimated*	*Historic during 11-year base period*
Verdugo Basin (5)	3,500[a]	1,640[a]
San Fernando Valley Area[b] (1, 2, 3, 4, 38 and 39)	247,260[a]	156,340[a]
Raymond Basin Area		
Western Unit[b] (7 and 8a)	11,900[a]	14,630[a]
Eastern Unit (8b)	2,540[c]	2,430
Way Hill Basin (12)	230	140
Foothill Basin (14)	670	560
San Dimas Basin (13)	2,330[a]	1,000
Spadra Basin (30)	510[a]	200[a]
Central San Gabriel Valley Area[b] (6, 9 and 10)	23,100[a]	24,250[a]
La Habra Basin (34)	3,440[a]	2,940[a]
Lower Los Angeles and San Gabriel Rivers Area—Nonpressure[b] (32, 33a, 33b and 36)	195,250[a]	128,580[a]
Claremont Heights Basin (17)	17,940	14,200
Live Oak Basin (18)	1,280	1,170
Pomona Basin (19)	8,860[a]	8,630[a]
Cucamonga Basin (20)	10,240	10,060
Rialto Basin (21a)	25,000	22,090
Lower Cajon Basin (40)	2,070	0
Lytle Basin (23)	17,760[c]	13,450
Devil Canyon Basin (24)	3,170	1,930
Yucaipa Basin (25a)	1,420	1,440
Beaumont Basin (25b)	1,800[c]	2,620
San Timoteo Basin (26)	3,610	3,800
Bunker Hill Basin (22)	73,170[a]	70,540[a]
Colton-Reche Canyon Area[b] (21b and 45)	73,910[a]	67,090[a]
Riverside-Arlington Area[b] (27 and 28)	10,790	12,760
Temescal Basin (29)	0	1,270
Chino Basin (16)	2,820[a]	1,930[a]
Irvine Basin (33d)	460[a]	320[a]
Lower Santa Ana River Area—Nonpressure[b] (33c, 35, 37 and 50)	16,390[a]	12,390[a]

[a] Includes sewage.
[b] Basins grouped for reasons stated in Chapter VI.
[c] Permissible export calculated.

SURFACE OUTFLOW

Surface outflow from each basin is a mixture of water from many sources. A part of it originates in runoff from tributary mountains and hills in large and small streams; a part in precipitation on valley lands overlying or upstream from the basin; and, where there is rising water, a portion originates in the ground water. Data upon which to base estimates of the amount from one source or another also vary widely in location and completeness from basin to basin. Because of this diversity, outflow from each source is discussed in Chapter VI in considerable detail for each basin. In those cases where a portion of the outflow is evaluated by subtracting percolation between a gaging station and the basin boundary, from recorded daily discharges at the station, a standard percolation diagram based on the Manning Formula for flow in open channels is used. Assuming a triangular stream cross section, and percolation proportional to wetted perimeter, the relationship between discharge and percolation, as determined by substitution of equivalent items in the formula, is expressed by a straight line having a slope of three on eight if plotted on log-log paper, as illustrated on Plate 23. Its location depends upon length of reach, relation of depth to width, roughness of channel, slope and unit rate of percolation, none of these factors, however, affecting the slope of the line.

If sufficient data were available to justify so doing, greater accuracy might be attained by using different curves for different periods, but in this study one curve only is used in the determination for each reach. In some cases its location is established by measured percolation during a part of the period considered, in others, judgment guided by comparison with reaches elsewhere fixes its position. In the discussion in Chapter VI the curve used is determined in each case by the point on the diagram where discharge and percolation are identical.

That portion of the outflow which originates on areas for which no usable stream-flow records are available is estimated as a percentage of inflow to, or of precipitation on such areas. Judgment as to the percentage used is guided by measured runoff from similar areas.

Rising Water

There are six general areas in South Coastal Basin in which rising water at present flows continuously. These are: (1), above Los Angeles Narrows; (2), above Whittier Narrows; (3), above Santa Ana Narrows; (4), above Bunker Hill Dike, which is the southerly boundary of Bunker Hill Basin; (5), in San Timoteo Canyon; and (6), across the Arlington-Temescal Basin boundary. This rising water constitutes part of the outflow from the basin in which it occurs, and a regulated supply to the basin below. In all save the first area cited it is in large part diverted for use. That in Los Angeles River, while reduced by pumping from the ground water close to the Narrows, is not diverted on the surface, and because the channel is paved across the portion of the Coastal Plain in which percolation is possible, i.e., the forebay area, very little of it reaches the ground water in the Coastal Plain.

In all cases, rising water occurs because the cross sectional area below the ground surface is not great enough to carry all the flow of the ground water stream which reaches it from the basin above. At many other points in the area where underflow is impeded, a steepening of the water table increases the velocity enough to offset restrictions in cross sectional area, and the water can still all flow underground. In areas of rising water, however, the slope of the water table is limited by the position and slope of the ground surface. As a result, water table and ground surface virtually coincide, not only at the restricted section, but for some distance above it. All ground water from above which cannot pass through underground with slope so fixed, drains into channels a little below the general ground level and flows through on the surface. Any change in the quantity reaching the section results primarily in a corresponding change in the rising water. Since elevation of the water table within the rising water area cannot fluctuate greatly, most of the change is accomplished through expansion or contraction of that area. A diagram which expressed the relationship between average elevation of the water table at Wells C-294 and C-294a, near Baldwin Park, and average amount of rising water at Whittier Narrows during the year is shown on Plate 24. A similar relationship exists in San Fernando Valley, and in the basins along Santa Ana River. While it is probably true that large variations in elevation of the water table in Chino Basin would also produce some change in the rising water outflow from it, records during the past 20 years indicate no definite relationship between the two. This may be because of the zone of dense material lying along the southerly boundary of the basin. Rising water from this basin varies more with fluctuations in precipitation than with changes in water table elevation.

Under natural conditions rising water formerly appeared at the surface at other points where now, because of increased net extractions from the ground water, the flow is all below ground. It is possible that increases in supply, through conservation of water now wasting, or decreases in extractions by substitution of an imported supply, may again so increase the volume of the ground water stream that water must again flow on the surface at some of these points.

Values of surface outflow presented in Table 12 include storm outflow and rising water. Except where noted, the 21-year period determines the long-time mean. A more detailed discussion of factors involved in derivation of values for each basin or group of basins appears in Chapter VI.

SUBSURFACE OUTFLOW

The hydrologic equation is the algebraic expression of the natural law that all water entering an area during any period of time must either go into storage within its boundaries, be consumed therein, exported therefrom, or flow out either on the surface or underground, during the same period. Through its use, any one of the items involved is determined if all others are known.

Change in storage underground in each of the basins is independently evaluated herein during the 11-year base period, 1927-28 to 1937-38, only. Since this is one of the terms of the equation, all other items involved, except subsurface outflow, are independently evaluated for the same period, and subsurface outflow is determined by solving the equation.

In nearly all cases considered herein, this historic base period subsurface outflow is also considered to be the long-time mean, either arbitrarily, as in those basins where excess or overdraft is evaluated, or because significant variation is improbable, as where rising water occurs. In five instances, however, the long-time mean under present conditions is considered to be different. These are: (1), Verdugo Basin, the subsurface outflow from which has been virtually eliminated by the construction of a submerged dam in Verdugo Canyon; and (2), Lower Cajon, (3), Devil Canyon, (4), San Timoteo and (5), Temescal Basins, in all of which subsurface outflow reacts quickly to changes in water table elevation, and in which it is therefore considered that the difference in demand in the two periods is balanced by change in subsurface outflow.

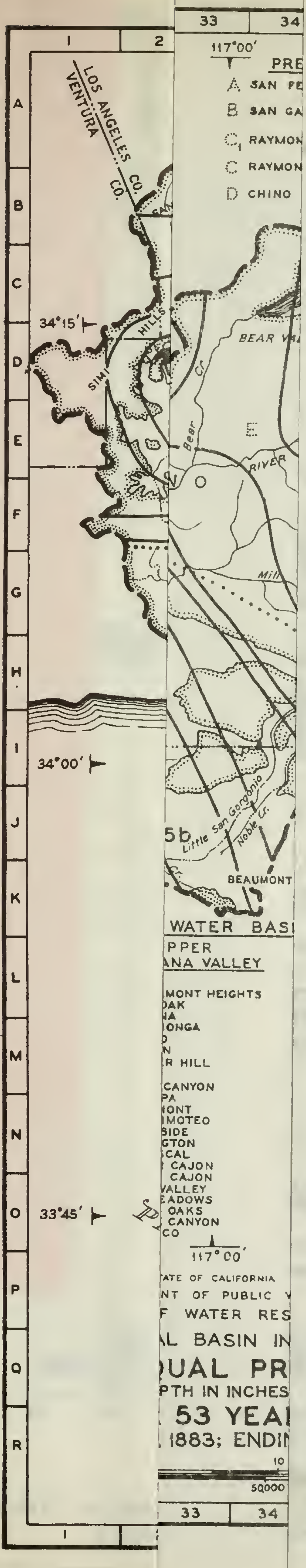
The values as derived in Chapter VI are presented in Table 12.

TABLE 12. ESTIMATED ANNUAL OUTFLOW FROM BASINS

(Acre-feet)

	Surface		*Subsurface*	
Basin name and number	*Long-time mean under present conditions*	*Historic 11-year base period average*	*Long-time mean under present conditions*	*Historic 11-year base period average* [a]
Verdugo Basin (5)	860	820	0	450
San Fernando Valley Area [b] (1, 2, 3, 4, 38 and 39)	22,040	20,360	7,110	7,110
Raymond Basin Area				
Western Unit [ab] (7 and 8a)	10,360	8,090	2,860	2,860
Eastern Unit (8b)	4,180	3,510	240	240
Glendora Basin (11)	1,130	1,190	3,420	3,420
Way Hill Basin (12)	230	210	890	890
Foothill Basin (14)	2,230 [a]	1,820	1,080	1,080
San Dimas Basin (13)	1,130	1,130	3,650	3,650
Spadra Basin (30)	1,240	1,210	1,150	1,150
Puente Basin (15)	3,810	3,730	2,740	2,740
Central San Gabriel Valley Area [b] (6, 9 and 10)	106,200 [a]	92,680	23,280	23,280
La Habra Basin (34)	2,690 [c]	2,580	5,620	5,620
Lower Los Angeles and San Gabriel Rivers Area—nonpressure [ab] (32, 33a, 33b and 36)	79,200	85,920	---	---
Claremont Heights Basin (17)	2,140	3,120	4,820	4,820
Live Oak Basin (18)	330	300	3,390	3,390
Pomona Basin (19)	1,180	1,140	520	520
Cucamonga Basin (20)	1,080	1,200	760	760
Rialto Basin (21a)	9,650	10,210	6,560	6,560
Lower Cajon Basin (40)	5,200	5,240	11,330 [a]	13,150
Lytle Basin (23)	4,060	5,430	590	590
Devil Canyon Basin (24)	4,100	4,250	5,160 [a]	3,950
Yucaipa Basin (25a)	1,320	1,300	2,920	2,920
Beaumont Basin (25b)	1,070	1,040	3,800	3,800
San Timoteo Basin (26)	2,230 [d]	1,740	13,960 [a]	16,730
Bunker Hill Basin (22)	38,440 [a]	38,190	20,110	20,110
Colton-Reche Canyon Area [b] (21b and 45)	29,130 [a]	27,510 [a]	20,110	20,110 [e]
Riverside-Arlington Area [b] (27 and 28)	55,030 [a]	50,100	8,550	8,550
Temescal Basin (29)	3,220	3,440	11,600 [a]	8,770
Chino Basin (16)	88,550	83,570	3,110	3,110
Irvine Basin (33d)	3,830	3,720	6,980	6,980
Lower Santa Ana River Area—nonpressure [b] (33c, 35, 37 and 50)	25,510	21,450	---	---

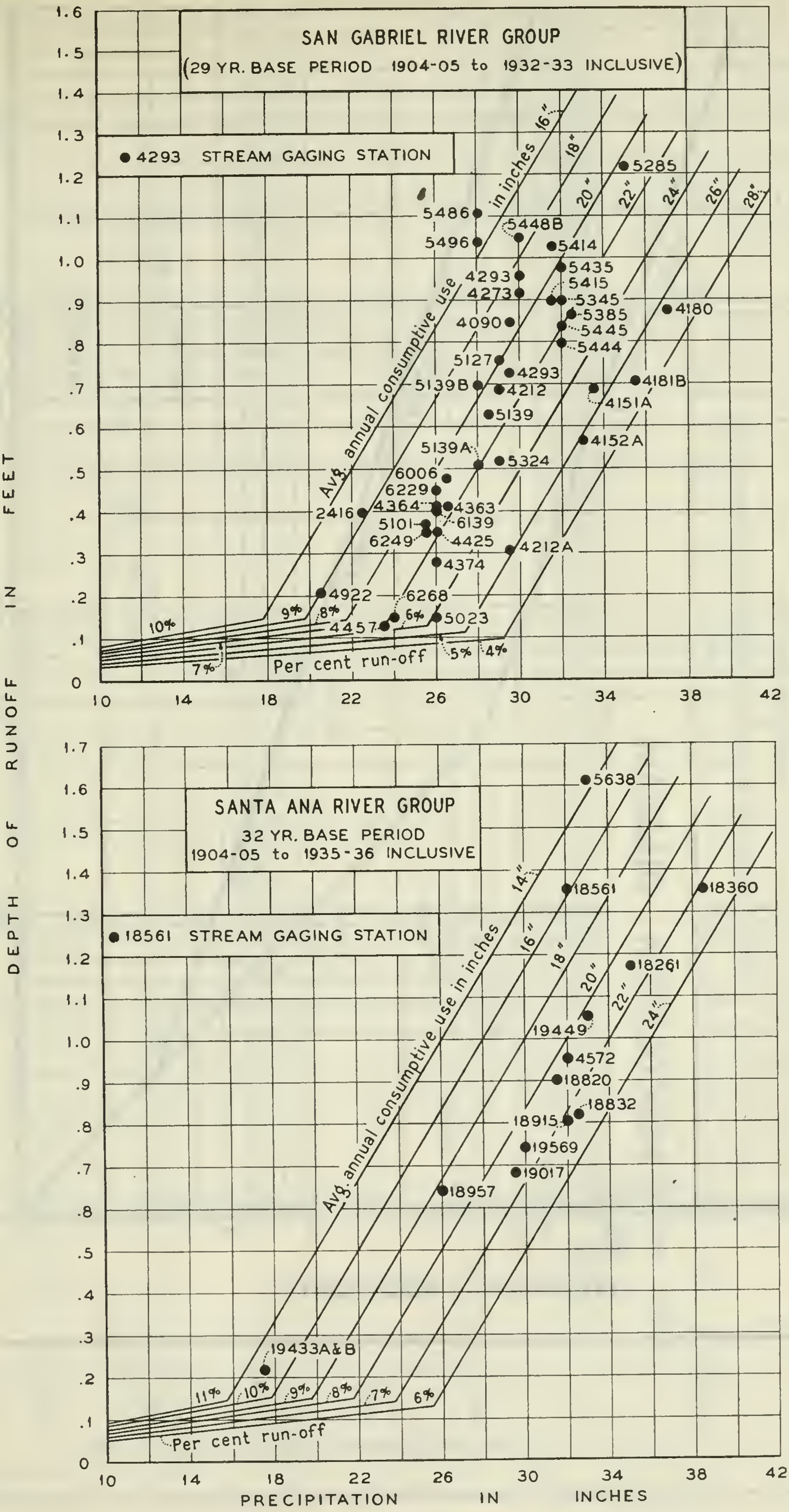
[a] Calculated by solving hydrologic equation.
[b] Basins grouped for reasons stated in Chapter VI.
[c] Average of 29- and 21-year mean annual values.
[d] 32-year mean annual value.
[e] Arbitrarily assumed same as subsurface inflow.



LOS ANGELES CO.
VENTURA CO.
34°15′
34°00′
33°45′
117°00′
PRE
A SAN PE
B SAN GA
C1 RAYMON
C RAYMON
D CHINO
BEAR VA
E
Bear Cr.
RIVER
Mill
SIMI
HILLS
Little San Gorgonio
Noble Cr.
5b
BEAUMONT
WATER BAS
PPER
ANA VALLEY
MONT HEIGHTS
R HILL
CANYON
MONT
MOTEO
SIDE
GTON
CAL
CAJON
CAJON
VALLEY
EADOWS
OAKS
CANYON
117°00′
TATE OF CALIFORNIA
NT OF PUBLIC
F WATER RES
L BASIN IN
UAL PR
PTH IN INCHES
53 YEA
1883; ENDI
10
50,000
1
2
33
34

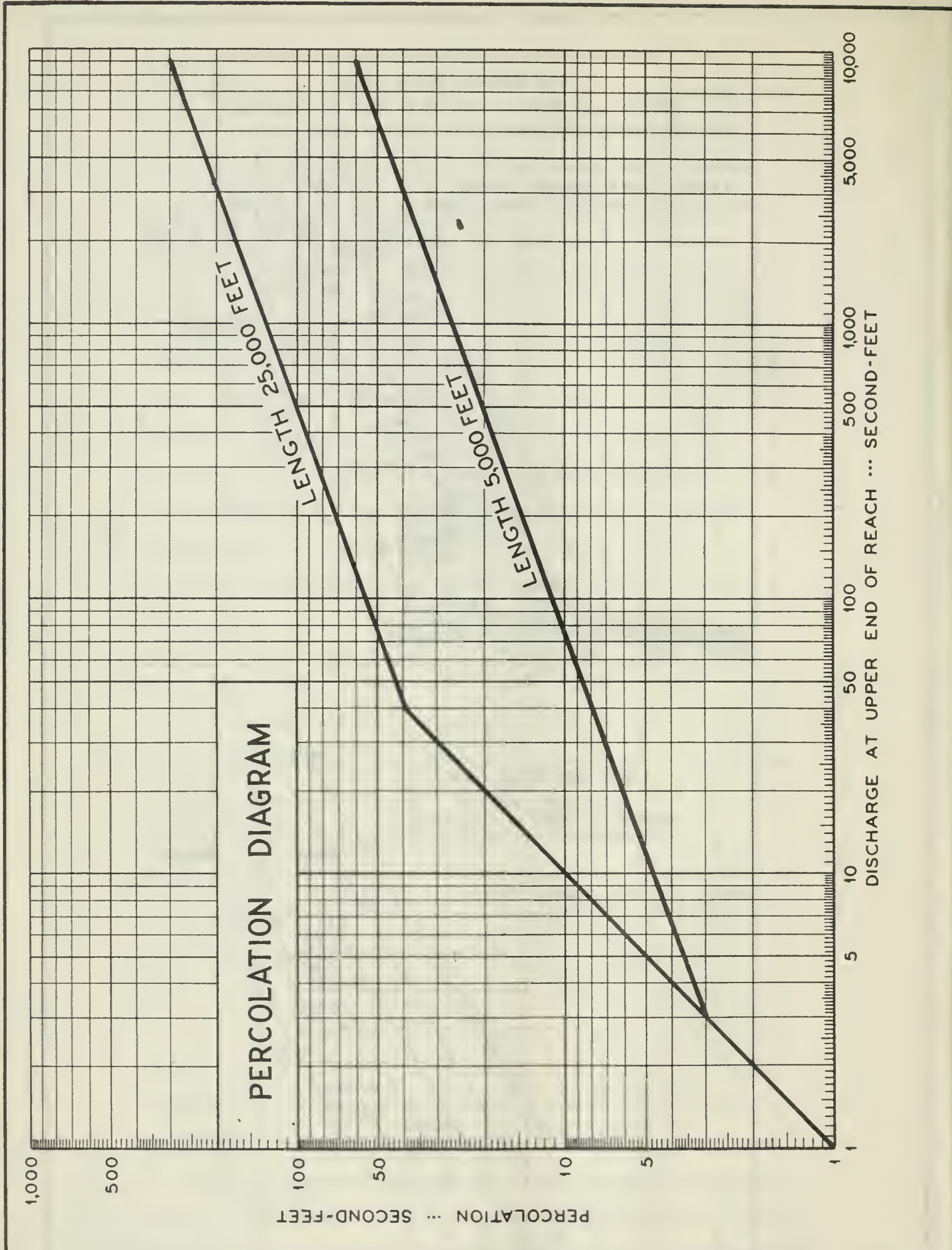
PLATE 21

LEGEND
WATERSHED BOUNDARY
EDGE OF NONWATER - BEARING AREA
GROUND WATER BASIN BOUNDARY
SUB-AREA BOUNDARY
APPROXIMATE BOUNDARY OF PRESSURE ZONE
6 GROUND WATER BASIN REFERENCE NUMBER
20 LINE OF EQUAL PRECIPITATION
BOUNDARY OF PRECIPITATION STATION GROUP
PRECIPITATION STATION GROUPS
A SAN FERNANDO
B SAN GABRIEL
C RAYMOND BASIN (MOUNTAIN)
C RAYMOND BASIN (VALLEY)
D CHINO
E BIG BEAR
F SAN BERNARDINO
G RIVERSIDE
H COASTAL PLAIN
GROUND WATER BASINS
SAN FERNANDO VALLEY
1 SAN FERNANDO
2 SYLMAR
3 TUJUNGA
4 PACOIMA
5 VERDUGO
38 BULL CANYON
39 LITTLE TUJUNGA
SAN GABRIEL VALLEY
6 MAIN SAN GABRIEL
7 MONK HILL
8a PASADENA
8b SANTA ANITA
9 UPPER CANYON
10 LOWER CANYON
11 GLENDORA
12 WAY - HILL
13 SAN DIMAS
14 FOOTHILL
15 PUENTE
30 SPADRA
UPPER SANTA ANA VALLEY
16 CHINO
17 CLAREMONT HEIGHTS
18 LIVE OAK
19 POMONA
20 CUCAMONGA
21a RIALTO
21b COLTON
22 BUNKER HILL
23 LYTLE
24 DEVIL CANYON
25a YUCAIPA
25b BEAUMONT
26 SAN TIMOTEO
27 RIVERSIDE
28 ARLINGTON
29 TEMESCAL
40 LOWER CAJON
41 UPPER CAJON
42 BEAR VALLEY
43 BIG MEADOWS
44 SEVEN OAKS
45 RECHE CANYON
46 CAJALCO
UPPER SANTA ANA VALLEY
47 LEE LAKE
48 COLDWATER
49 BEDFORD
COASTAL PLAIN
31a WEST COASTAL PLAIN - NORTH
31b WEST COASTAL PLAIN - SOUTH
32 HOLLYWOOD
33a LOS ANGELES
33b MONTEBELLO
33c SANTA ANA
33d IRVINE
33e CENTRAL COASTAL PLAIN PRESSURE
33f EAST COASTAL PLAIN PRESSURE
34 LA HABRA
35 YORBA LINDA
36 LOS ANGELES NARROWS
37 SANTA ANA NARROWS
50 SANTIAGO
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SOUTH COASTAL BASIN INVESTIGATION
LINES OF EQUAL PRECIPITATION
DEPTH IN INCHES
MEAN FOR 53 YEAR PERIOD
BEGINNING JULY 1, 1883; ENDING JUNE 30, 1938
0 5 10 15 MILES
FEET 0 25,000 50,000 75,000
PACIFIC OCEAN
San Pedro Bay
Santa Monica Bay
LOS ANGELES
SANTA MONICA
LONG BEACH
LOS ANGELES HARBOR
SANTA ANA
CORONA
RIVERSIDE
SAN BERNARDINO
POMONA
BEAUMONT
SAN FERNANDO
Prado Dam
Lake Elsinore
Lake Mathews
BEAR VALLEY RES.
SAN GABRIEL MTS.
SAN BERNARDINO MTS.
SANTA MONICA MTS.
SANTA ANA MTS.
SAN JOAQUIN HILLS
SAN PEDRO HILLS
PUENTE HILLS
SAN JOSE HILLS



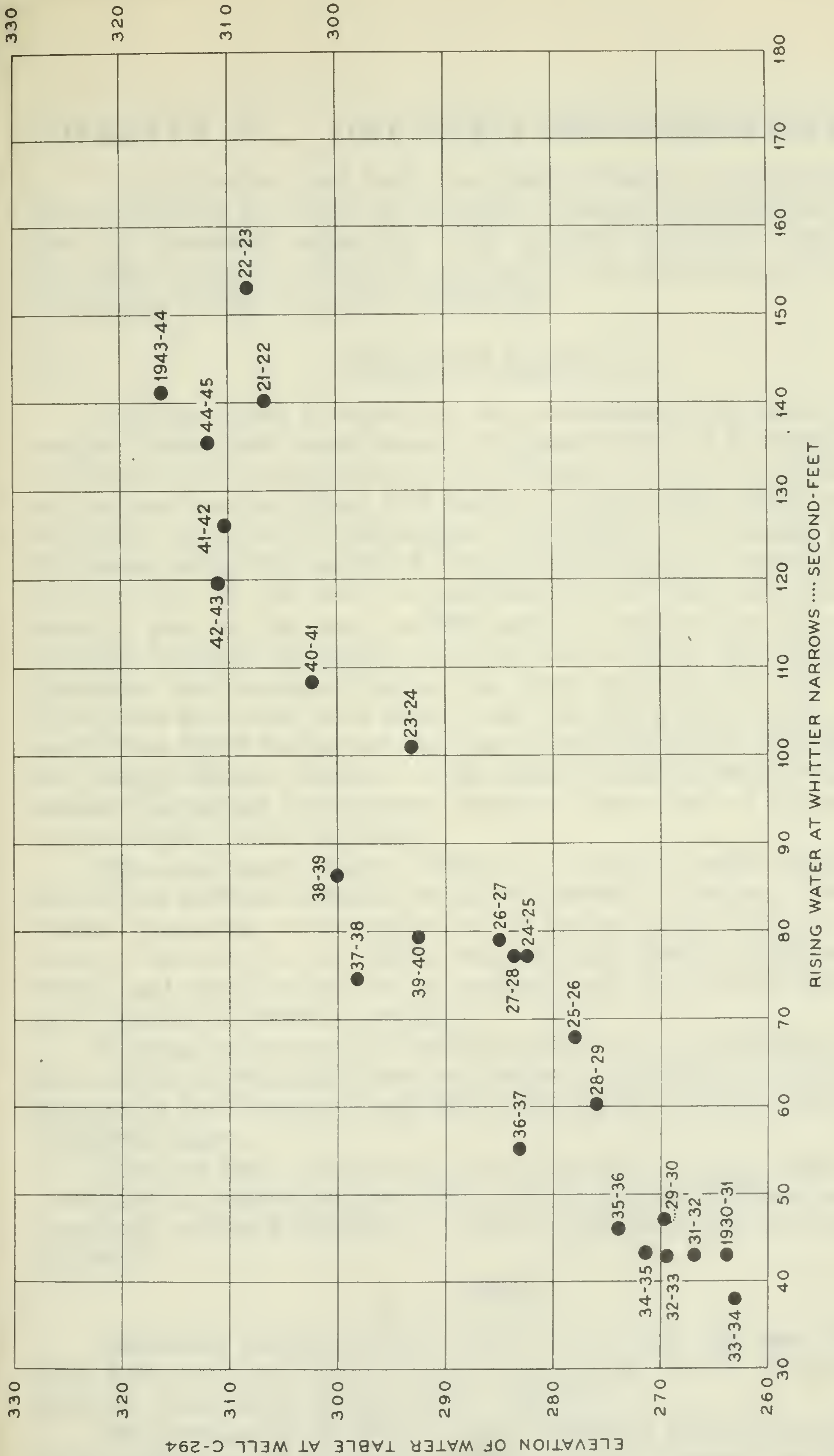
RELATION BETWEEN
LONG TIME MEAN PRECIPITATION & DEPTH OF RUNOFF
FOR MOUNTAIN WATERSHEDS

PLATE 23



PERCOLATION DIAGRAM
LENGTH 25,000 FEET
LENGTH 5,000 FEET
DISCHARGE AT UPPER END OF REACH ... SECOND-FEET
1
5
10
50
100
500
1,000
5,000
10,000
PERCOLATION ... SECOND-FEET
1
5
10
50
100
500
1,000

PLATE 24



RELATIONSHIP OF RISING WATER AT WHITTIER NARROWS
TO WATER TABLE ELEVATION AT WELL C-294

CHAPTER VI. DETAILED DISCUSSION OF BASINS

In this chapter each basin, or group of basins in those cases where interconnection is so close as to render separate consideration meaningless, is discussed separately. The general principles presented in preceding chapters are herein applied in the derivation of values summarized in Tables 5, 8, 9, 10, 11 and 12.

VERDUGO BASIN (5)

Verdugo Basin is located in the northeasterly portion of San Fernando Valley, and covers about 6.9 square miles. It is bounded on the northwest by Tujunga Basin, on the northeast by San Gabriel Mountains, on the southeast by Monk Hill Basin and San Rafael Hills, and on the southwest by Verdugo Mountains. Topography in the main portion of this basin, which lies north of Verdugo Mountains, is relatively smooth with a slope to the south approximating 500 feet per mile. In the easterly part of this main portion and in Verdugo Canyon, which lies between Verdugo Mountains and San Rafael Hills, the surface is more irregular. In Verdugo Canyon the slope averages 150 feet per mile. Elevations above sea level range from 700 feet at the canyon mouth, to more than 2,000 feet along the San Gabriel Mountain boundary. Soils are mostly lighter members of the Hanford series, and are quite permeable. Municipal development occupies a large part of the valley area, as well as portions of the hills.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on valley lands, inflow from 3,080 acres of mountains and 5,370 acres of hills directly tributary to the basin, and small inflow on the surface from Monk Hill Basin. There is no import of water or sewage.

A considerable part of surface inflow and precipitation flows out into the San Fernando Basin, and water is exported in relatively large amount to San Fernando and Monk Hill Basins. Sewage outflow is also relatively large.

For this basin, long-time mean annual net supply under present conditions is somewhat less than present annual demand, so a small overdraft exists. Evaluation of items required to estimate its amount follows.*

Inflow

Estimated annual surface inflow to the basin averages 2,850 acre-feet, 2,630 acre-feet and 2,470 acre-feet during the 29-, 21- and 11-year periods, respectively, as derived in Table 13.

The estimate of the 29-year mean values of inflow from 3,080 acres of mountains and 5,370 acres of hills directly tributary to the basin is based on the assumption that, if water is available, average consumptive

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

use on the mountain area is 22 inches and that on the hill area 19 inches, inflow from the hills, however, being never less than 8½ percent of precipitation on them. Average inflow from the mountains during the 11-year base period is estimated to be 0.78 times the 29-year mean, this being the ratio between 11- and 29-year mean annual discharge of San Gabriel River. Estimated 11-year average inflow from the hills is 0.98 times the 29-year mean, being proportional to precipitation on the area as represented by the San Fernando Valley Group. Corresponding ratios for the 21-year period are 0.83 for mountains and 1.03 for hills.†

The only surface inflow from other basins is that small part of the surface outflow from Monk Hill Basin which originates in the extreme westerly part of that basin.

Subsurface inflow, other than that referred to by note in the table, is negligible.

TABLE 13. SURFACE INFLOW TO VERDUGO BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Estimated [a]	1,540	1,280	1,200
From directly tributary hills			
Estimated [a]	1,100	1,140	1,080
From other basins			
Monk Hill	210	210	190
Total	2,850	2,630	2,470

[a] Includes a relatively small amount of underflow.

Consumptive Use

In Table 14 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. Because of its topography, Verdugo Basin is best suited for domestic occupancy, and that type of culture now covers about one-half the basin. Natural vegetation growing on the relatively large area of unused land ranges from moderately heavy brush to light brush, weeds and grass.

† If runoff from hills were assumed to follow the same regimen of flow as San Gabriel River, mean annual inflow from them during the 21-year period would be 920 acre-feet and that during the 11-year period 860 acre-feet.

TABLE 14. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN VERDUGO BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley area					
Avocado and citrus	2.0	0	0	5	10
Deciduous	1.8	68	122	18	32
Irrigated grass	3.0	109	327	119	357
Domestic and industrial	1.6	1,959	3,134	2,224	3,558
Unirrigated	----	2,280	----	2,050	----
29-year period	1.7	----	----	----	3,485
21-year period	1.726	----	----	----	3,538
11-year period	1.681	----	3,833	----	----
Subtotal	----	4,416	----	4,416	----
29-year period	----	----	----	----	7,442
21-year period	----	----	----	----	7,495
11-year period	----	----	7,416	----	----
Hill area					
Deciduous	0.3 [a]	10	3	10	3
Irrigated grass	1.5 [a]	1	2	1	2
Domestic and industrial	0.1 [a]	183	18	338	34
Subtotal	----	194	23	349	39
Grand total	----	4,610	----	4,765	----
29-year period	----	----	----	----	7,481
21-year period	----	----	----	----	7,534
11-year period	----	----	7,439	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 15 estimated values of exports of water and sewage for each year since 1927-28 are presented. Export of water is to Monk Hill and San Fernando Basins, and averaged 780 acre-feet annually during the 11-year period. Sewage goes to the ocean, and averages 860 acre-feet annually. Total average annual export then was 1,640 acre-feet during the 11-year base period.

It is estimated that annual export to Monk Hill Basin under present conditions is equal to the 1943-44 value. Export to San Fernando Basin, consisting of underflow diverted at the lower end of Verdugo Canyon by a submerged dam, has been high during recent years of heavy rainfall. It cannot be expected to maintain its present high value over a long time cycle of supply. It is estimated that annual export for use to San Fernando Basin under present conditions is 75 percent of the average for the eight year period, 1936-37 to 1943-44, during which rainfall in Verdugo Mountains was about 133 percent of normal. Total long-time average annual export for use from the basin under present conditions is estimated to be 1,470 acre-feet.

The 1944-45 value of 2,030 acre-feet is considered to represent average annual sewage outflow under present conditions. Total average annual export under present conditions is therefore estimated at 3,500 acre-feet.

TABLE 15. EXPORT FROM VERDUGO BASIN

Year	Acre-feet Water	Acre-feet Sewage	Year	Acre-feet Water	Acre-feet Sewage
1927-28	1,440	140	1936-37	630	1,190
1928-29	1,950	200	1937-38	910	1,290
1929-30	1,730	340	1938-39	1,710	1,650
1930-31	420	940	1939-40	1,560	1,880
1931-32	320	1,060	1940-41	1,990	2,180
1932-33	200	950	1941-42	1,870	2,160
1933-34	—90	1,080	1942-43	2,000	1,930
1934-35	440	1,090	1943-44	2,290	1,970
1935-36	640	1,130	1944-45	2,060	2,030

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and hills, part of the inflow from Monk Hill Basin, and runoff originating in precipitation on the valley overlying Verdugo Basin.

Inflow from mountains is distributed in several streams which flow southward across La Crescenta Valley into Verdugo Creek, which skirts the northeasterly toe of the Verdugo Hills, and then flows southerly through Verdugo Canyon and across the basin boundary at its mouth. The channel of Verdugo Creek is paved below the debris basin near the upper end of the canyon, as are channels of most tributary streams which enter from the north above the basin. The main stream of Verdugo Creek is not paved for a distance of two and three-fourths miles above the debris basin. Percolation opportunity for mountain water and inflow from directly tributary hills is largely confined to this reach. A large part of the hill inflow enters the paved section directly, as does most of the inflow from Monk Hill Basin.

Discharge at Station 3953, measured during the period 1929-30 to 1932-33, inclusive, and estimated from its relationship with Flint Wash at Station 4010 during the years 1927-28, 1928-29, and 1933-34 to 1937-38, inclusive, determines estimated 11-year average annual outflow as 820 acre-feet. This is 7.4 percent of average annual inflow to and precipitation on the basin during the 11-year period. Assuming the percentage relationship the same for the longer periods, resultant mean annual value of surface outflow under present conditions in both 29- and 21-year periods is 860 acre-feet.

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period must, in accordance with principles set forth in Chapter V, have averaged 450 acre-feet annually, as derived in Table 16. Subsurface outflow is considered negligible under present conditions due to reconstruction in 1936 of a submerged dam across the lower end of Verdugo Canyon.

TABLE 16. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM VERDUGO BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	8,570	
Surface inflow	2,470	
Subtotal		11,040
Increase in storage in basin	690	
Water leaving basin on surface		
Surface outflow	820	
Exported water	780	
Exported sewage	860	
Consumptive use	7,440	
Subtotal		10,590
SUBSURFACE OUTFLOW—to San Fernando Valley Area		450

Overdraft

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual overdraft is 240 acre-feet, as derived in Table 17. In this basin substitution of 29-year mean values results in the same answer.

TABLE 17. ESTIMATED ANNUAL OVERDRAFT IN VERDUGO BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual rise in storage during base period	----	----	----	690
Items tending to increase the rise				
Precipitation	9,020	8,570	450	
Surface inflow	2,630	2,470	160	
Subtotal to be added				610
Items tending to decrease the rise				
Consumptive use	7,530	7,440	90	
Export	3,500	1,640	1,860	
Surface outflow	860	820	40	
Subsurface outflow	0 [a]	450	—450	
Subtotal to be subtracted				1,540
OVERDRAFT				240

[a] Subsurface outflow reduced to negligible amount by submerged dam at lower end of Verdugo Canyon rebuilt and enlarged in 1936.

SAN FERNANDO VALLEY AREA

San Fernando Basin (1)
Sylmar Basin (2)
Tujunga Basin (3)
Pacoima Basin (4)
Bull Canyon Basin (38)
Little Tujunga Basin (39)

All of these contiguous basins, with the exception of Bull Canyon and Little Tujunga from which extractions are negligible and for which available data are very meager, lie almost entirely within the City of Los Angeles, and have available to them the large supply imported through the Owens Valley-Mono Basin Aqueduct. For this reason they are treated as a unit.

Topography varies greatly from one basin to another. The surface of San Fernando Basin is relatively smooth, with gentle slope to the south toward Los Angeles River over the westerly three-quarters of the basin, and steeper slope in the same direction adjacent to Verdugo Mountains, north of and including part of Burbank and Glendale. Sylmar Basin is also relatively smooth, with average slope to the south ranging between 90 and 160 feet per mile. Along its southwest boundary the land is rolling. In the westerly one-third of Tujunga Basin the valley surface shows no large irregularities, but is cut by many small channels. Slope here is to the south and averages 75 feet per mile. The middle third is in large part covered by the wash of Tujunga Creek, and slope is to the west also at about 75 feet per mile, with a relatively narrow strip of usable land which slopes steeply to the south. East of Tujunga Creek the basin occupies the westerly extremity of the long depression between Verdugo and San Gabriel Mountains. Here the slope is to the west at an average rate of 200 feet or more to the mile. In the west and north central portions of Pacoima Basin topography is smooth but steep, with slope toward the south ranging from 180 to 300 feet per mile. Elsewhere the land is rolling, and east of Pacoima Creek the same folded but water-bearing beds which underlie Bull Canyon and Little Tujunga Basins result in steep and irregular topography. Topography of Bull Canyon Basin is more rolling than that of Pacoima Basin, while that of Little Tujunga Basin is more rugged. Elevations above sea level in San Fernando Valley Area range from about 400 feet at the lower boundary of San Fernando Basin, to 3,200 feet at the highest point in Little Tujunga Basin. Soils and general cultural development have been discussed in Chapter II.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on valley lands, inflow from 212 square miles of mountains and 65 square miles of hills directly tributary to the basin, and surface inflow from Verdugo Basin. In addition to the large supply from the Owens Valley-Mono Basin aqueduct of the City of Los Angeles, water is imported from Verdugo Basin, and from Colorado River by the Metropolitan Water District.

A considerable part of the surface inflow and precipitation flows out into the Coastal Plain, and water originating in both local and Owens Valley-Mono Basin sources is exported in large amount to West Coast, Hollywood, Los Angeles Narrows, and Main San Gabriel Basins and to Los Angeles and Montebello Forebay Areas. Sewage outflow is also large.

For the area as a whole, and for each of its component basins, long-time mean annual net supply under present conditions is greater than present annual demand, so an excess exists. Evaluation of items required * to estimate its amount follows.

Inflow

Estimated surface inflow to the area averages 49,670 acre-feet, 40,650 acre-feet, and 35,130 acre-feet annually in the 29-, 21- and 11-year periods, respectively, as derived in Table 18.

Inflow from directly tributary mountain and hill area, above gaging stations at which flow was measured during period of several years, is tabulated below. Twenty-nine year mean annual values for Pacoima and Tujunga Creeks, and both 29- and 21-year values for Haines Creek, are estimated by comparison with San Gabriel River. One year of missing record for Haines Creek during the 11-year period is estimated by comparison with Big Tujunga Creek. Average annual runoff of Sycamore Canyon for all three periods is estimated by comparison with San Gabriel River.

		Mean annual inflow in acre-feet		
Stream	*Station*	*29-year period*	*21-year period*	*11-year period*
Pacoima Creek	6006	8,770[a]	6,660[a]	5,590[b]
Haines Creek	5023	150	120	80
Tujunga Creek	6129–39	26,810[a]	21,200[a]	17,480[b]
Sycamore Canyon	3974	370	310	290
Total		36,100	28,290	23,440

[a] Measured runoff adjusted for change in reservoir storage, but not corrected for reservoir evaporation.
[b] Actual runoff, uncorrected for reservoir operation.

The estimate of 29-year mean annual inflow from 48,510 acres of mountains directly tributary to the area, and draining in below gaging stations, and from 40,100 acres of tributary hills is based on the assumption that, if water is available, average annual consumptive use on both mountain and hill area tributary to San Fernando and Sylmar Basins is 20 inches, and on that tributary to Tujunga, Pacoima, Bull Canyon and Little Tujunga Basins, 19 inches. However, it is further assumed that runoff is never less than 8 and 8½ percent of precipitation on that area tributary to the two groups of basins, respectively. Inflow from mountains during the 11-year base period is estimated to be 0.78 times the 29-year mean, this being the ratio between 11- and 29-year mean annual discharge of San Gabriel River. Estimated 11-year mean annual inflow from hills is 0.98 times the 29-year mean, being proportional to precipitation on the area represented by the San Fernando Valley Group. Corresponding ratios for the 21-year period are 0.83 for mountains and 1.03 for hills.†

Inflow on the surface from other basins consists of outflow from Verdugo Basin.

Subsurface inflow, other than that indicated by note in Table 18, is estimated to be negligible under present conditions. The submerged dam across the lower end of Verdugo Canyon was reconstructed in 1936,

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

† If runoff from hills is assumed to follow the same regimen of flow as San Gabriel River, mean annual inflow during the 21-year period is reduced to 3,970 acre-feet, and for the 11-year period to 3,730 acre-feet.

and since that time nearly all underflow has been diverted for use. During the 11-year period it averaged 450 acre-feet annually.

TABLE 18. SURFACE INFLOW TO SAN FERNANDO VALLEY AREA

Average annual for 29-year period, 1904-05 to 932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Measured during all or part of period	35,730	27,980	23,150
All estimated [a]	7,930	6,580	6,190
From directly tributary hills			
Measured during part of period	370	310	290
All estimated [a]	4,780	4,920	4,680
From other basins			
Verdugo	860	860	820
Total	49,670	40,650	35,130

[a] Includes a relatively small amount of underflow.

Import

In Table 19 estimated values of imports of water for each year since 1927-28 are presented. There is no sewage import. During the 11-year period, an annual average of 209,690 acre-feet of water was imported, 208,920 acre-feet from the Owens Valley by the City of Los Angeles, and the remainder from Verdugo and Los Angeles Narrows Basins.

Los Angeles Aqueduct imports in 1943-44 and 1944-45 were 274,500 and 266,370 acre-feet, respectively. The long-time mean quantity which can be imported with present facilities in the Owens Valley-Mono Basin Aqueduct is estimated to be 307,000 acre-feet annually. Since this amount can be brought in at little additional cost, it is considered to be the import from that source under present conditions.

Imports from Colorado River by the Metropolitan Water District started in 1940-41, when 320 acre-feet were brought in. In 1942-43, 1,200 acre-feet were imported, in 1943-44, 710 acre-feet, and in 1944-45, 580 acre-feet. The 1943-44 value is assumed to be average annual import from this source under present conditions.

Imports from Los Angeles Narrows Basin have remained approximately constant, and for present conditions are assumed to equal the average for the 11-year period.

Imports from Verdugo Basin consist of underflow diverted at a submerged dam at the lower end of Verdugo Canyon, and have been high during recent years of high water table and heavy rainfall. They cannot be expected to maintain their present high value over a long-time cycle of supply. It is estimated that annual average import from this source under present conditions is 75 percent of the average for the eight years of record, 1936-37 to 1943-44, inclusive, during which rainfall in Verdugo Mountains averaged 133 percent of normal.

Total import to San Fernando Valley Area under present conditions is estimated to be 308,760 acre-feet annually.

TABLE 19. IMPORT TO SAN FERNANDO VALLEY AREA

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	196,230	1933-34	185,480	1939-40	218,500
1928-29	192,140	1934-35	195,280	1940-41	203,660
1929-30	199,920	1935-36	237,590	1941-42	248,190
1930-31	216,220	1936-37	206,780	1942-43	267,190
1931-32	238,500	1937-38	209,780	1943-44	277,070
1932-33	228,620	1938-39	238,770	1944-45	268,600

Consumptive Use

In Table 20 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Areal distribution of irrigated culture is discussed in Chapter II and unit consumptive use in Chapter V. Estimates of evaporation from reservoirs are based upon 12 years of record, 1932 to 1943, inclusive.

TABLE 20. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN SAN FERNANDO VALLEY AREA

Type of culture	*Unit consumptive use, feet*	*1932*		*1942*	
		Acres	*Acre-feet*	*Acres*	*Acre-feet*
Valley and folded area					
Garden and field	1.7	20,352	34,598	20,920	35,564
Avocado and citrus	2.5	9,381	23,452	11,021	27,552
Deciduous	2.3	14,241	32,754	12,021	27,648
Alfalfa	3.0	6,907	20,721	7,117	21,351
Irrigated grass	3.0	971	2,913	879	2,637
Domestic and industrial	1.6	27,456	43,930	33,926	54,282
Evaporation from reservoirs	----	993	5,054	993	5,054
Unirrigated:					
29-year period	1,273	----	----	42,541	54,155
21-year period	1,292	----	----	42,541	54,963
11-year period	1,250	49,117	61,396	----	----
Subtotal	----	129,418	----	129,418	----
29-year period	----	----	----	----	228,243
21-year period	----	----	----	----	229,051
11-year period	----	----	224,818	----	----
Hill and mountain area					
Garden and field	0.4 [a]	306	122	326	130
Avocado and citrus	1.2 [a]	938	1,126	1,073	1,288
Deciduous	1.0 [a]	173	173	168	168
Alfalfa	1.7 [a]	12	20	82	139
Irrigated grass	1.7 [a]	280	476	260	442
Domestic and industrial	0.3 [a]	1,803	541	2,480	744
Evaporation from distributing reservoir	----	68	265 [b]	68	265 [b]
Subtotal	----	3,580	2,723	4,457	3,176
Grand total	----	132,998	----	133,875	----
29-year period	----	----	----	----	231,419
21-year period	----	----	----	----	232,227
11-year period	----	----	227,541	----	----

[a] Difference between irrigated culture and natural vegetation.
[b] Difference between reservoir evaporation and natural consumptive use from same area.

Export

In Table 21 estimated values of exports of water and sewage for each year since 1927-28 are presented. During the 11-year period, 1927-28 to 1937-38, inclusive, an annual average of 150,560 acre-feet of water was exported for use. Sewage outflow from the area averaged 5,780 acre-feet annually. Total average annual export then was 156,340 acre-feet during the 11-year base period.

Estimated total average annual export under present conditions is 229,590 acre-feet of water and 17,670 acre-feet of sewage, a total of 247,260 acre-feet, equal to the value for 1944-45.

TABLE 21. EXPORT FROM SAN FERNANDO VALLEY AREA
(Acre-feet)

Year	Water	Sewage	Year	Water	Sewage
1927-28	138,970	1,800	1936-37	163,680	9,030
1928-29	145,180	2,920	1937-38	169,660	9,880
1929-30	146,830	3,670	1938-39	177,940	10,870
1930-31	153,430	4,300	1939-40	174,980	11,670
1931-32	152,810	5,520	1940-41	174,430	15,500
1932-33	148,140	5,600	1941-42	180,440	15,510
1933-34	140,970	5,790	1942-43	198,290	16,540
1934-35	137,450	7,240	1943-44	216,850	17,870
1935-36	159,000	7,810	1944-45	229,590	17,670

Surface Outflow

Estimated surface outflow from the area averages 24,450 acre-feet, 22,040 acre-feet and 20,360 acre-feet annually in the 29-, 21- and 11-year periods respectively as derived in Table 22.

Virtually all outflow is in Los Angeles River. This stream has been measured since 1929-30 at Station 2771, four miles downstream from the San Fernando Basin boundary, where, during the 11-year period outflow is estimated to have averaged 21,850 acre-feet per year. From low flow measurements it is further estimated that 3,320 acre-feet of this was rising water*, and 18,530 acre-feet storm outflow. In 1937-38 estimated rising water increased abruptly to about 22,000 acre-feet annually, and has been large since then. This increase is presumed to be partly due to higher water table in the area north of the river, and partly to recent lowering of the river channel for flood control improvements.

A portion of the outflow originates in mountains and varies with mountain runoff. By application of percolation curves, and use of daily discharges of Tujunga and Pacoima Creeks near points where they emerge from the mountains, the ratio between 29- and 11-year average discharge from these streams into Los Angeles River is estimated as 1.36. It is also estimated that approximately one-third the average discharge at Station 2771, below the valley boundary, originates in mountains, and two-thirds in hills and on valley lands, outflow from which should vary approximately with precipitation on them. By giving the ratio between 29- and 11-year average precipitation, i.e., 1.02, twice the weight assigned the above 1.36 ratio, it is estimated that 29-year mean annual discharge at Station 2771 under present conditions, exclusive of rising water, is 13 percent greater than the 11-year average, or 20,940 acre-feet. On the same basis, difference between 11- and 21-year mean is negligible.

Only a few records of operation of Hansen and Sepulveda Reservoirs are as yet available, and there is some uncertainty as to future operation. Their effect on outflow from the area under present operation is believed small, and has not been numerically evaluated.

Average annual precipitation on hills and valley land tributary to Los Angeles Narrows Basin above Station 2771 and below the valley boundary, varies but little in the three periods, and contribution to outflow from that source in both 29- and 21-year periods is estimated to be the same as that during the 11-year period, i.e., 1,490 acre-feet.

The amount of rising water in any year, and over a long period of years, not only varies with elevation of the water table in San Fernando Basin, but is affected by the amount of extraction near the Narrows, and by recent lowering of the channel. It is arbitrarily assumed that average elevation of the water table may be so reduced that the long-time mean annual value for rising water is 5,000 acre-feet.

TABLE 22. SURFACE OUTFLOW FROM SAN FERNANDO VALLEY AREA

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
Measured during part of period			
Storm outflow	20,940	18,530	18,530
Rising water	5,000	5,000	3,320
Subtotal	25,940	23,530	21,850
Estimated, originating in			
Precipitation on hills and valley land above Station 2771 and below valley boundary	1,490	1,490	1,490
Remainder	24,450	22,040	20,360

Excess

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual excess is 25,490 acre-feet, as derived in Table 23. If the 29-year mean values are substituted, the derived value is 27,420 acre-feet.

The foregoing figures are predicated on two assumptions: First, that the 1944-45 value represents "present" export, and second that the average maximum amount which can be brought in through the Owens Valley-Mono Basin Aqueduct annually during a period of long-time mean supply represents "present" import from that source. Under the second assumption, aqueduct water is treated as part of the local supply. This is logical for several reasons: (1) The greater part of the directly used supply to the area comes from that source; (2) A considerable part of the deep percolation into the area is aqueduct water, or results from its use on the surface; (3) All local water, as well as aqueduct water, is available to the city when needed; (4) Wide variation in aqueduct flow in recent years, from 185,600 acre-feet in 1933-34 to 274,500 acre-feet in

* Includes relatively small amounts of industrial wastes, discharge from distribution lines, etc.

1943-44, makes it extremely difficult to establish a value for "present" import comparable to those established in other basins; (5) So long as the required water is available in Owens Valley and Mono Basin, and can be brought in with present facilities, no overdraft can develop.

The excess is of course actually in Owens Valley and Mono Basin, rather than in San Fernando Valley Area. As is true of an excess from local sources it must, if brought in and spread in the valley over a period of years, add to outflow as rising water until such time as it is needed. It differs from excess local water, however, in that it can be used or wasted before reaching the area, or can be wasted directly into Los Angeles River, in which case it would have little or no effect on the average elevation of the water table or the amount of rising water.

TABLE 23. ESTIMATED ANNUAL EXCESS IN SAN FERNANDO VALLEY AREA UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual rise in storage during base period	----	----	----	9,370
Items tending to increase the rise				
Precipitation	184,720	175,450	9,270	
Surface inflow	40,650	35,130	5,520	
Subsurface inflow	0	450	—450	
Import	308,760	209,690	99,070	
Subtotal to be added				113,410
Items tending to decrease the rise				
Consumptive use	232,230	227,540	4,690	
Export	247,260	156,340	90,920	
Surface outflow	22,040	20,360	1,680	
Subtotal to be subtracted				97,290
Excess				25,490

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period must, in accordance with principles set forth in Chapter V, have averaged 7,110 acre-feet annually, as derived in Table 24. By comparison with independently determined underflow at Whittier Narrows and Santa Ana Narrows, 7,110 acre-feet average annual subsurface outflow at Los Angeles Narrows, while possibly a little high, is not far enough out of line to be significant so far as evaluation of excess is concerned. An increase of 0.1 foot in value of unit consumptive use assigned garden and field crops would decrease calculated subsurface outflow by 2,040 acre-feet, and estimated excess by only 60 acre-feet. A similar increase in value for unirrigated lands would decrease subsurface outflow 4,910 acre-feet, and increase excess by a little less than 700 acre-feet.

TABLE 24. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM SAN FERNANDO VALLEY AREA DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering San Fernando Valley Area		
Precipitation	175,450	
Surface inflow	35,130	
Subsurface inflow	450	
Import	209,690	
Subtotal		420,720
Increase in storage	9,370	
Water leaving on surface		
Surface outflow	20,360	
Exported water	150,560	
Exported sewage	5,780	
Consumptive use	227,540	
Subtotal		413,610
SUBSURFACE OUTFLOW—to Los Angeles Narrows Basin		7,110

WESTERN UNIT OF RAYMOND BASIN AREA

Monk Hill Basin (7)

Pasadena Sub-area (8a)

This area is operated as a unit in administration of Raymond Basin Watermaster Service Area, and is so treated here. It is located in the northwest portion of San Gabriel Valley, and covers about 36 square miles. It is bounded on the southwest and west by San Rafael Hills, on the northwest by Verdugo Basin, on the north and northeast by San Gabriel Mountains, on the east by Eastern Unit of Raymond Basin Area, and on the southeast and south by Raymond Fault, across which lies Main San Gabriel Basin. Topography is for the most part fairly smooth, but exhibits some irregularity along Arroyo Seco, in the upper reaches of Eaton Creek, just north of the westerly one-third of Raymond Fault, and in portions of the La Crescenta trough. The slope is generally to the south, and ranges from 100 feet per mile in the lower portions to 300 feet per mile near the mountains. Elevations above sea level range from 500 feet near the southeasterly corner of Pasadena Sub-area, to 1,800 feet in the westerly portion of Monk Hill Basin. Soils covering the area are about equally divided between lighter members of the Hanford and Ramona series, with a few scattered areas of Placentia soils. Hanford soils predominate in Monk Hill Basin and on either side of Eaton Wash and Arroyo Seco, while Ramona soils cover most of the west central portion of Pasadena Sub-area. Municipal development occupies about 60 percent of the area, about 10 percent is devoted to agriculture, and the remainder is in a more or less natural state being covered by trees, brush, weeds and grass.

The local water supply, utilized to a considerable extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on valley lands, and inflow from 23,170 acres of mountains and 1,750 acres of hills directly tributary to the area. Imported water provides a relatively large addition to the supply.

A considerable part of the surface inflow and precipitation flows out into Los Angeles Narrows and Main San Gabriel Basins, together with some underflow, and there is small surface outflow to Verdugo Basin. Water is exported in relatively large amount to Main San Gabriel Basin, and in lesser quantity to Los Angeles Narrows Basin. Sewage outflow is also relatively large.

Water rights in the Western Unit of Raymond Basin Area have recently been adjudicated,* and extractions are now limited to safe yield. This eliminates the possibility of overdraft, which under conditions as of 1937-38 amounted to 6,000 acre-feet annually. The court retains jurisdiction, so that future adjustments in rights may be made when necessary due to changed conditions. The court appointed the Division of Water Resources as Watermaster, and service started July 1, 1944.

With two exceptions, all major producers from the area have signed a water exchange agreement. Under this plan, any entity which does not need all water available to it under its decreed right, or which can import additional water, offers its surplus water from sources within the area for sale on a year-to-year basis to those parties whose rights are not sufficient to meet their demands. Thus, deficit in supply is made up by some decrease in exports, and an increase in imports.

Present demand, for use within the area and for export, is greater than available local supply. This necessitates import of considerable magnitude. The long-time mean annual amount of this import under present conditions is estimated herein. Evaluation of items required † for this estimate, follows.

Inflow

Estimated annual surface inflow to the unit averages 15,620 acre-feet, 13,170 acre-feet and 11,650 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 25.

Annual inflow in Arroyo Seco, from above Station 5127 at which flow was measured during all or part of each period, averages 7,770 acre-feet, 6,610 acre-feet, and 5,730 acre-feet during the three periods. That in Eaton Creek above Station 4090 averages 3,510 acre-feet, 2,900 acre-feet and 2,450 acre-feet. For Arroyo Seco the 29-year mean annual value is derived by comparison with San Gabriel River, while for Eaton Creek it is estimated by comparison with San Gabriel River and Arroyo Seco.

The estimate of 29-year mean annual inflow from mountains and hills directly tributary to Monk Hill Basin, and downstream from Station 5127 is based on the assumption that, if water is available, average annual consumptive use from mountain area is 21 inches, and that from hill area 19 inches, inflow however never being less than 7½ percent of precipitation on mountains and 8½ percent of that on hills. For areas tributary to Pasadena Sub-area below Station 4090, consumptive use on mountains is assumed to be 20 inches, and that on hills 18 inches. Average inflow from mountains during the 11-year period is estimated to be 0.78 times the 29-year mean, this being the ratio between 11- and 29-year mean discharge of San Gabriel River. That from hills is 0.99 times the 29-year mean, being proportional to precipitation on the area represented by the

* *City of Pasadena* v. *City of Alhambra, et al.*, Case No. Pasadena C-1323, Superior Court, Los Angeles County, December 23, 1944.

† Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Raymond Basin Group. Corresponding ratios for the 21-year period are 0.83 and 1.02.*

Subsurface inflow, other than that indicated by note in Table 25, is negligible.

TABLE 25. SURFACE INFLOW TO WESTERN UNIT OF RAYMOND BASIN AREA

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year peirod*
From directly tributary mountains			
Measured during all or part of period	11,280	9,510	8,180
All estimated [a]	3,980	3,300	3,110
From directly tributary hills			
All estimated [a]	360	360	360
Total	15,620	13,170	11,650

[a] Includes a relatively small amount of underflow.

Historical Import

In Table 26, estimated values of imports of water for each year since 1927-28 are presented. There is no sewage inflow. Water is now imported from Eastern Unit of Raymond Basin Area, Verdugo Basin, San Gabriel Basin, and Colorado River. From 1933-34 to 1940-41, inclusive, water was imported from Morris Reservoir on San Gabriel River. During the 11-year period a total annual average of 3,480 acre-feet was imported.

TABLE 26. IMPORT TO WESTERN UNIT OF RAYMOND BASIN AREA

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	460	1933-34	5,330	1939-40	13,990
1928-29	470	1934-35	7,830	1940-41	6,240
1929-30	560	1935-36	2,230	1941-42	1,320
1930-31	600	1936-37	7,190	1942-43	1,080
1931-32	580	1937-38	12,400	1943-44	3,460
1932-33	580	1938-39	13,600	1944-45	6,560

Consumptive Use

In Table 27 an estimate of consumptive use, based on a detailed culture survey conducted by the City of Pasadena in 1935, 1938 and 1939, is presented. Unit values were estimated largely from soil moisture tests. Culture is mostly of municipal type, the cities of Pasadena and San Marino, together with their unincorporated suburbs, occupying the greater part of the area. Industrial development is small. Natural vegetation growing on unused lands is mostly light brush, weeds and grass, with a few areas covered by trees and undergrowth.

* If inflow from hills is assumed to follow the same regimen of flow as San Gabriel River, inflow during the 21- and 11-year periods as estimated at 300 and 280 acre-feet respectively.

Change in consumptive use due to cultural development has been small enough so that the value derived in the table is considered average for present conditions as well as for the 11-year period.

TABLE 27. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN WESTERN UNIT OF RAYMOND BASIN AREA

Cultural classification	*Unit consumptive use, feet*	*Acres*	*Acre-feet*
Estates	2.07	2,604	5,390
Class A residential	1.92	2,167	4,160
Class B residential	1.88	3,170	5,960
Rural residential	1.78	765	1,362
Commercial	0.50	193	96
Semicommercial	1.32	532	702
Reservoir sites	1.34	63	84
Parks	2.40	453	1,087
Schools	1.63	272	443
Lawns	3.00	4	12
Lawn and shrubs	3.00	1	3
Lawn and trees	3.33	63	210
Shrubs	2.33	4	9
Ornamental trees	1.58	1,481	2,340
Avocado and citrus	2.00	904	1,808
Deciduous	1.75	294	514
Truck and nursery	3.00	296	888
Vineyard	1.67	1,024	1,710
Brush	1.67	2,275	3,799
Vacant	1.50	2,252	3,378
Riverwash	0.99	354	351
Streets	0.50	3,722	1,860
Totals		22,893	36,166

Export

In Table 28 estimated values of water and sewage exported for each year since 1927-28 are presented. Water is exported to Main San Gabriel and Los Angeles Narrows Basins, while sewage is discharged into Rio Hondo in Main San Gabriel Basin. During the 11-year period an annual average of 9,500 acre-feet of water and 5,130 acre-feet of sewage, a total of 14,630 acre-feet, was exported.

Export of water, by all but one exporter, is now limited to decreed rights unless additional water is purchased by exporters under the Water Exchange Agreement. It is estimated that average annual export under present conditions is 4,620 acre-feet, determined as follows. Export to Los Angeles Narrows Basin is assumed to equal the amount actually exported in 1944-45. The estimate of average annual export to Main San Gabriel Basin under present conditions is based upon decreed rights of exporters, use of water in exporters' service areas within the Western Unit in 1944-45, and amounts offered for sale by exporters under the Water Exchange Agreement for the Fiscal Year 1946-47.

Annual export of sewage under present conditions is assumed to equal that of 1944-45, or 7,280 acre-feet.

Estimated total annual export under present conditions then is 11,900 acre-feet.

TABLE 28. EXPORT FROM WESTERN UNIT OF RAYMOND BASIN AREA

Year	*Acre-feet* *Water*	*Acre-feet* *Sewage*	*Year*	*Acre-feet* *Water*	*Acre-feet* *Sewage*
1927-28	10,610	4,260	1936-37	8,090	5,730
1928-29	10,110	4,660	1937-38	7,710	5,920
1929-30	10,200	4,650	1938-39	8,260	6,060
1930-31	10,400	4,900	1939-40	8,860	6,170
1931-32	9,580	5,320	1940-41	8,410	6,490
1932-33	9,570	5,070	1941-42	9,140	6,340
1933-34	10,320	5,140	1942-43	9,720	6,550
1934-35	8,300	5,300	1943-44	8,860	6,970
1935-36	9,650	5,470	1944-45	6,390	7,280

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and hills, and runoff originating in precipitation on valley lands within the area, and is estimated to average 11,580 acre-feet, 10,360 acre-feet and 8,090 acre-feet annually in the 29-, 21- and 11-year periods, respectively, as derived in Table 29.

The greater part of inflow from directly tributary mountains, as well as a considerable part of that originating elsewhere, is in Arroyo Seco and Eaton Creek. Parital regulation of flood flows is provided in Devils Gate Reservoir on Arroyo Seco at the lower boundary of Monk Hill Basin and in Eaton Wash Reservoir on Eaton Creek one and one-half miles above Colorado Street.

ARROYO SECO

Outflow in Arroyo Seco has been measured since 1925-26 at Station 4035 at the lower boundary of the area, with exception of 1927-28 and 1928-29 during which years there was no release from Devils Gate Reservoir, and for which years outflow is estimated by comparison with Seco Drain. During the 11-year period, estimated outflow in Arroyo Seco averaged 2,620 acre-feet annually.

Best available information indicates that in the immediate future Devils Gate Reservoir will be operated principally for flood control, with little storage of water for conservation. In the past, conservation storage has amounted to about 25 percent of capacity during winter flood months, with no limit after April 15th. Henceforth, except for temporary detention of large flood flows, it is probable that the greater part of the water reaching the reservoir in suitable volume will be used for sluicing debris from behind the dam. To compensate for resultant loss of conservation in the reservoir, it is assumed that maximum spreading will be resorted to upstream. Below Devil's Gate to the lower boundary of the area the channel of Arroyo Seco is completely lined, except for a confined section one-quarter mile long just below the dam, where percolation is considered negligible.

Twenty-nine and 21-year mean outflow under present conditions, of water originating in upper Arroyo Seco sources, is estimated as follows. Mean daily discharges of Arroyo Seco at Station 5139B, just above the point of diversion by Pasadena Water Department, were measured from 1923-24 through 1931-32. For other years from 1913-14 through 1942-43, except 1915-16, mean daily discharges at this station are estimated by comparison with flows at Station 5127, one and one-half miles upstream. Of mean daily flows past Station 5139B, it is assumed that all flows up to 20 second-feet are diverted for use, but that no diversion is made when discharge is in excess of 100 second-feet. It is further assumed that, of mean daily flows past the diversion point, all up to 150 second-feet are added to the ground water by artificial spreading and natural percolation between the diversion point and reservoir, but that no spreading is done when flows exceed 150 second-feet. Natural percolation between canyon mouth and reservoir is estimated by use of a percolation curve with 20 second-feet all percolating. For those years of the 29-year period prior to the beginning of record at Station 5127, and for 1915-16, outflow from these upper Arroyo Seco sources is estimated by comparison with San Gabriel River.

Additional outflow in Arroyo Seco originating on areas draining in below Station 5139B, is considered in five parts, in the first four of which sufficient record is available to esablish a relationship between outflow and precipitation at valley stations of the Raymond Basin Group, by means of which outflow during years of missing record is estimated. (1) Runoff in Altadena Storm Drain, which enters Arroyo Seco one-eighth mile below Station 5139B, was measured at Station 5139C from 1925-26 to 1932-33, inclusive. It is assumed that, of monthly discharges in excess of 20 acre-feet, one-half constitutes outflow. (2) Flows from Flint Wash, measured at Station 4010 from 1923-24 to date, and from (3) West Altadena Storm Drain, measured at Station 4021A from 1937-38 to date, enter immediately above Devils Gate Dam, with so little percolation opportunity that all runoff there is assumed to constitute outflow from the unit. (4) Outflow from sources tributary below Devil's Gate, under conditions the same as at present, has been measured from 1937-38 to date by the difference between releases from the reservoir and flows at Station 4035. (5) Unmeasured outflow from areas tributary to Devil's Gate below gaging Station 5139B is estimated to be all of the inflow from 240 acres of hills, 50 percent of that from 14 acres of mountains, and 6 percent of the precipitation on 810 acres of valley land.

Resultant estimated annual surface outflow in Arroyo Seco under present conditions averages 6,180 acre-feet during the 29-year period and 4,820 acre-feet during the 21-year period.

EATON CREEK

Outflow in Eaton Creek was measured at Station 4117, just below the area boundary, from 1929-30 to 1935-36, inclusive, with exception of the year 1931-32. It has been measured at Station 4116, one-half mile above the boundary, since 1938-39. Discharge for years of missing record during the 11-year period is estimated by comparison with measured flow of Eaton Creek at Stations 2941A and 4090. Resultant average annual outflow in Eaton Creek during the 11-year base period is 1,100 acre-feet.

Rainfall on valley area and inflow from mountains both averaged greater during the 29- and 21-year periods than during the base period. Sufficient records are not yet available to determine accurately the effect of Eaton Wash Reservoir on outflow, but percolation has been increased, and it is therefore estimated that both 29- and 21-year outflow in Eaton Creek averages the same as during the 11-year period, 1,100 acre-feet annually.

BROADWAY, GRANADA AND RUBIO DRAINS

Outflow in Broadway Drain has been measured at Stations 4057 or 4068 for all except a few months since 1923-24. That in Granada Drain has been measured at Station 4057A since 1935-36, and for Rubio Drain records of outflow at Station 4108 are available for all except a few months from 1923-24 to date. Discharges in each of these drains during missing or incomplete years of the 11-year period are estimated by comparison with flow in Seco Drain. Total average outflow in the three is estimated at 2,810 acre-feet annually during the 11-year base period. For the 29- and 21-year periods, outflow during years of missing record is estimated from its relationship with precipitation at valley stations of the Raymond Basin Group. Total average annual outflow in the drains during the 29-year period is thus estimated at 2,660 acre-feet, and that during the 21-year period at 2,810 acre-feet.

UNMEASURED OUTFLOW

It is estimated that unmeasured outflow from those portions of the area not draining into the above channels includes 25 percent of the inflow from tributary mountains, all of that from hills, and a portion of the precipitation on valley land ranging from 9 percent of that on a small area tributary to Verdugo Creek, to 17 percent of that in the southerly part of the City of Pasadena.

TABLE 29. SURFACE OUTFLOW FROM WESTERN UNIT OF RAYMOND BASIN AREA

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
To Verdugo Basin			
Estimated, originating in:			
Directly tributary mountains and hills	90	70	70
Precipitation on valley land	130	140	130
Subtotal	220	210	200
To Los Angeles Narrows Basin			
Measured during part of period	6,180	4,820	2,620
To Central San Gabriel Valley Area			
Measured during part of period	3,760	3,910	3,910
Estimated, originating in			
Directly tributary mountains	190	160	150
Precipitation on valley land	1,230	1,260	1,210
Subtotal	5,180	5,330	5,270
Total	11,580	10,360	8,090

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period must, in accordance with principles set forth in Chapter V, have averaged 2,860 acre-feet annually, as derived in Table 30.

TABLE 30. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM WESTERN UNIT OF RAYMOND BASIN AREA DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering area		
Precipitation	40,810	
Surface inflow	11,650	
Import	3,480	
Decrease in storage in area	5,810	
Subtotal		61,750
Water leaving area on surface		
Surface outflow	8,090	
Exported water	9,500	
Exported sewage	5,130	
Consumptive use	36,170	
Subtotal		58,890
SUBSURFACE OUTFLOW—to Central San Gabriel Valley Area		2,860

Required Long-time Mean Import Under Present Conditions

The hydrologic equation used in the preceding article applies equally well for any period. Since extractions are now limited to safe yield, there can be neither excess nor overdraft, and net change in storage over a cycle of long-time mean supply must be zero. Assuming that subsurface outflow is the same in all periods, items involved in the equation, other than required import, have been evaluated for both 29- and 21-year cycles. If the 21-year period is assumed to represent the cycle of long-time mean supply, required long-time mean annual import is 5,910 acre-feet, as derived in Table 31. If the 29-year period is so considered, the derived value is 5,540 acre-feet.

These values are predicated on the assumption that a large part of the runoff in Arroyo Seco is conserved by spreading. It is estimated that an annual average of 960 acre-feet can be so conserved over the 21-year period. If this is not done, required import will be correspondingly greater.

As sewer systems, now authorized, are installed for presently unsewered areas in County Sanitation Districts Nos. 15 and 17, required import will be further increased by the amount of any additional sewage outflow.

TABLE 31. ESTIMATED REQUIRED AVERAGE ANNUAL IMPORT TO WESTERN UNIT OF RAYMOND BASIN AREA UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE A CYCLE OF LONG-TIME MEAN SUPPLY

Demand on area	Acre-feet	
Consumptive use	36,170	
Exported water	4,620	
Exported sewage	7,280	
Surface outflow	10,360	
Subsurface outflow	2,860	
Subtotal		61,290
Supply to area exclusive of import		
Precipitation	42,210	
Surface inflow	13,170	
Subtotal		55,380
REQUIRED IMPORT		5,910

EASTERN UNIT OF RAYMOND BASIN AREA

Santa Anita Sub-area (8b)

Santa Anita Sub-area of Raymond Basin is located in the northwesterly portion of San Gabriel Valley, and covers about 3.6 square miles. It is bounded on the west by Pasadena Sub-area, on the northeast and east by San Gabriel Mountains, and on the south and southeast by Raymond Fault, beyond which lies Main San Gabriel Basin. Topography is quite regular throughout, with slopes from 150 to 600 feet per mile, increasing toward the mountains. Elevations above sea level range from 525 to about 1,400 feet. Soils covering this area are mostly lighter members of the Hanford series, with scattered areas of Ramona and Placentia soils, and some of the heavier Chino soils just above Raymond Fault. Municipal development occupies about 32 percent of the area, about 22 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized to some extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on the valley, and inflow from 10,510 acres of mountains directly tributary to the area. There is no import of water or sewage.

A considerable part of the surface inflow and precipitation flows out into Main San Gabriel Basin together with some underflow, and water is exported in relatively large amount to Main San Gabriel Basin and the Western Unit of Raymond Basin Area.

Water rights in the Eastern Unit of Raymond Basin Area have recently been adjudicated,* and extractions are now limited to safe yield of the basin. The court retains jurisdiction so that future adjustments in rights may be made when necessary due to changed conditions. Watermaster service by the Division of Water Resources started on July 1, 1944.

Under the above conditions there can be no overdraft. Present demand for use within the area is somewhat less than available supply,

* Case No. Pasadena C-1323, Superior Court, Los Angeles County, December 23, 1944.

and the excess is exported. Such adjustment as is necessary to make demand equal safe yield must be made in the amount exported. Therefore, long-time mean permissible export under present conditions is derived herein. Evaluation of items required* to estimate its amount, follows.

Inflow

Estimated annual surface inflow to the unit averages 7,410 acre-feet, 6,410 acre-feet and 5,780 acre-feet annually in the 29-, 21- and 11-year periods, respectively, as derived in Table 32.

Annual inflow from directly tributary mountain area, above gaging stations at which runoff has been measured during a part of each period, is tabulated below. Twenty-nine year mean annual values are derived by comparison with San Gabriel River.

		Mean annual inflow in acre-feet		
Stream	*Station*	*29-year period*	*21-year period*	*11-year period*
Little Santa Anita	4151A	810	700	600
Big Santa Anita	4180	5,270	4,610	4,140
Total		6,080	5,310	4,740

The estimate of 29-year mean annual inflow from 3,300 acres of mountains directly tributary to the unit, and downstream from gaging stations at which above inflow was measured, is based on the assumption that, if water is available, average consumptive use on mountain area is 22 inches, inflow however being never less than seven percent of precipitation on the mountains. The 11-year value is estimated to be 0.78 times the 29-year mean, this being the ratio between 11- and 29-year mean discharge of San Gabriel River. The corresponding ratio for the 21-year period is 0.83.

Subsurface inflow, other than that indicated by note in Table 32, is negligible.

TABLE 32. SURFACE INFLOW TO EASTERN UNIT OF RAYMOND BASIN AREA

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Measured during part of period[a]	6,080	5,310	4,740
Estimated[b]	1,330	1,100	1,040
Total	7,410	6,410	5,780

[a] Evaporation loss in Big Santa Anita Reservoir is considered negligible and values given are not corrected for this loss.

[b] Includes a relatively small amount of underflow.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Consumptive Use

In Table 33 an estimate of consumptive use based on a detailed culture survey conducted by the City of Pasadena in 1935, 1938 and 1939 is presented. Unit values are estimated largely from soil moisture tests. Municipal development includes the City of Sierra Madre and a portion of the City of Arcadia. Industrial development is negligible. Natural vegetation growing on unused land ranges from heavy brush in the northwesterly portion of the basin, to light brush, weeds and grass elsewhere, with scattered trees in the southerly portion.

Change in consumptive use due to cultural development has been small enough so that the values derived in Table 33 are considered average for present conditions as well as for the 11-year period.

TABLE 33. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN EASTERN UNIT OF RAYMOND BASIN AREA

Cultural classification	*Unit consumptive use, feet*	*Acres*	*Acre-feet*
Estates	2.07	217	449
Class A residential	1.92	79	152
Class B residential	1.88	90	169
Rural residential	1.78	83	148
Commercial	0.50	6	3
Semicommercial	1.32	2	3
Reservoir sites	1.34	8	11
Schools	1.63	6	10
Vacant	1.50	313	469
Ornamental trees	1.58	444	701
Avocado and citrus	2.00	296	592
Deciduous	1.75	4	7
Vineyard	1.67	5	8
Brush	1.67	204	340
Truck and nursery	3.00	206	618
Riverwash	0.99	101	100
Streets	0.50	260	130
Total		2,324	3,910

Historical Export

In Table 34 estimated values of exports of water, to Main San Gabriel Basin and Western Unit of Raymond Basin Area, for each year since 1927-28 are presented. There is no sewage outflow. During the 11-year period, an annual average of 2,430 acre-feet of water was exported.

TABLE 34. EXPORT FROM EASTERN UNIT OF RAYMOND BASIN AREA

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	2,620	1933-34	2,700	1939-40	2,800
1928-29	2,410	1934-35	1,640	1940-41	3,130
1929-30	2,280	1935-36	2,200	1941-42	3,690
1930-31	2,530	1936-37	2,850	1942-43	3,620
1931-32	2,230	1937-38	3,100	1943-44	4,100
1932-33	2,190	1938-39	2,660	1944-45	2,700

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and runoff originating in precipitation on valley lands within the unit. It is estimated to average 4,410 acre-feet, 4,180 acre-feet and 3,510 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 35.

Most of the inflow from directly tributary mountains is in Big Santa Anita Creek, which for one and one-half miles skirts the mountains bordering the area on the east. In this reach high bed-rock beneath the channel limits percolation. The upper reach of Little Santa Anita Creek below its canyon mouth has been lined since 1928, and lining of the channel throughout its length above its junction with Big Santa Anita Creek was completed in 1940. Spreading grounds on Little Santa Anita compensate to some extent for resultant decrease in natural percolation, although no records of amount of water spread are available. Regulation of Big Santa Anita Creek by the flood control reservoir two and one-half miles upstream from Foothill Boulevard has little effect on outflow from the area, because of restricted percolation in the channel above the area boundary.

Outflow from the area in Santa Anita Creek has been measured at Stations 4174 and 4174B during the periods 1923-24 to 1926-27, and 1938-39 to date, inclusive. A reasonably close relationship was found to exist between this measured outflow and combined yearly runoff at the two mountain gaging stations, 4180 and 4151A, on Big and Little Santa Anita Creeks, respectively, at which flow has been measured since 1916-17. Estimates of runoff at these latter two stations for years prior to beginning of record were made by comparison with San Gabriel River. Using these measured and estimated values of runoff at upper mountain stations, and the relationship of measured runoff to measured outflow mentioned above, outflow from the area for years of no record was estimated.

It is estimated that outflow from the portion of the area not tributary to the two main streams includes 25 percent of inflow from directly tributary mountains, and 11 percent of precipitation on the valley land.

TABLE 35. SURFACE OUTFLOW FROM EASTERN UNIT OF RAYMOND BASIN AREA

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
Measured during part of period	4,190	3,950	3,290
Estimated, originating in			
Directly tributary mountains	10	10	10
Precipitation on valley land	210	220	210
Total	4,410	4,180	3,510

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must, in accordance with principles set forth in Chapter V, have averaged 240 acre-feet annually, as derived in Table 36.

TABLE 36. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM EASTERN UNIT OF RAYMOND BASIN AREA DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering area		
Precipitation	4,310	
Surface inflow	5,780	
Water coming from storage in area	0	
Subtotal		10,090
Water leaving area on surface		
Surface outflow	3,510	
Export	2,430	
Consumptive use	3,910	
Subtotal		9,850
SUBSURFACE OUTFLOW—to Central San Gabriel Valley Area		240

Long-time Mean Amount Available for Export

The hydrologic equation used in the foregoing article applies equally well in any period. Since there is neither excess nor overdraft, net change in storage over a cycle of long-time mean supply is zero. Assuming that subsurface outflow is the same in all periods, all items involved except export have been evaluated for both 29- and 21-year cycles. If the 21-year period is assumed to represent the cycle of long-time mean supply, mean annual export is 2,540 acre-feet, as derived in Table 37. If the 29-year period is so considered, the value is 3,220 acre-feet, derived by substituting 29-year mean values of precipitation, surface inflow, and surface outflow in the table.

The value derived for the 21-year period is considered more reliable, since stream flow data for that period are more complete than for the 29-year period. Further, it is the more conservative of the two values. It is therefore estimated that 2,540 acre-feet can be exported annually under present conditions without progressive and permanent change in the water table elevation.

As the sewerage improvements now authorized are installed, and sewage is exported to the ocean, allowable export for use will be decreased by the amount of sewage outflow.

TABLE 37. ESTIMATED AVERAGE ANNUAL AMOUNT AVAILABLE FOR EXPORT FROM EASTERN UNIT OF RAYMOND BASIN AREA UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Acre-feet	
Supply to area		
Precipitation	4,460	
Surface inflow	6,410	
Subtotal		10,870
Demand on area, exclusive of export		
Consumptive use	3,910	
Surface outflow	4,180	
Subsurface outflow	240	
Subtotal		8,330
Available for export		2,540

GLENDORA BASIN (11)

Glendora Basin is located in the northeasterly portion of San Gabriel Valley, and covers about 5.2 square miles. It is bounded on the west by Main San Gabriel and Lower Canyon Basins, on the north and northeast by San Gabriel Mountains, and on the south by Way Hill Basin and Way Hill. Except for a small area at its eastern extremity topography of this basin is smooth. The southwesterly trending slope down the well marked cone of Big and Little Dalton Creeks varies between 100 and 150 feet per mile. Easterly from hills which border the basin on the south, topography is rolling. Elevations above sea level range from 700 to 1,100 feet. Soils covering this basin are almost entirely lighter members of the Hanford series and are quite absorptive. Municipal development occupies about 10 percent of the area, 79 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originiates in precipitation on the valley, and inflow from 10,200 acres of mountains and 420 acres of hills directly tributary to the basin. Imported water provides a relatively large addition to the supply.

A considerable part of the surface inflow and precipitation flows into Main San Gabriel Basin, together with some underflow. There is no export of water or sewage.

In this basin, long-time mean annual net supply under present conditions is greater than present annual demand, so an excess exists. Evaluation of items required to estimate its amount follows.*

Inflow

Estimated annual surface inflow to the basin averages 3,100 acre-feet, 2,550 acre-feet and 2,280 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 38.

Annual inflow from directly tributary mountain area, above gaging stations at which the flow was measured during a part of each period, is

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

tabulated below. The 29-year value for Big Dalton Creek is derived by comparison with San Gabriel River and San Dimas Creek. Values for Little Dalton Creek for all three periods are derived by comparison with Big Dalton Creek.

		Annual inflow in acre-feet		
Stream	*Station*	*29-year period*	*21-year period*	*11-year period*
Little Dalton	4364	850	690	610
Big Dalton	4374	1,300[a]	1,050[a]	910[b]
Total		2,150	1,740	1,520

[a] Measured discharge, plus diversions, corrected for change in reservoir storage but not corrected for reservoir losses.
[b] Actual flow including diversions, uncorrected for reservoir operation.

The estimate of 29-year mean annual inflow from 3,410 acres of mountains directly tributary to the basin, and downstream from gaging stations at which above inflow was measured, and from 420 acres of directly tributary hills is based on the assumption that, if water is available, average consumptive use on the mountain area is 20 inches and that on the hill area 17 inches, inflow values, however, being never less than 8 percent of the precipitation on the mountains and 9½ percent of that on the hills. The 11-year value for mountains is estimated to be 0.78 times the 29-year mean, this being the ratio between 11- and 29-year mean discharge of San Gabriel River. That for hills is 0.98 times the 29-year mean, being proportional to precipitation on the area represented by the San Gabriel Valley Group. Corresponding ratios for the 21-year period are 0.83 for mountains and 1.00 for hills.*

Subsurface inflow, other than that referred to by note in Table 38, is negligible.

TABLE 38. SURFACE INFLOW TO GLENDORA BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Measured during part of period	2,150	1,740	1,520
Estimated [a]	850	710	660
From directly tributary hills			
Estimated [a]	100	100	100
Total	3,100	2,550	2,280

[a] Includes a relatively small amount of underflow.

Import

In Table 39 estimated values of imports of water for each year since 1927-28 are presented. There is no import of sewage. During the 11-year period, an annual average of 2,910 acre-feet of water was imported from pumped sources in Main San Gabriel and San Dimas Basins.

* If inflow from hills is assumed to follow the same regimen of flow as San Gabriel River, 21- and 11-year average values each equal 80 acre-feet.

The amount of water imported depends to some extent upon the amount of gravity water available from Big Dalton and Little Dalton Creeks. It is therefore estimated that average annual import under present conditions is 2,760 acre-feet, equal to the average import for the four-year period 1941-42 to 1944-45 inclusive, plus the difference between four year and 21-year average gravity diversions from Big and Little Dalton Creeks.

TABLE 39. IMPORT TO GLENDORA BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	2,380	1933-34	3,790	1939-40	2,220
1928-29	2,530	1934-35	1,960	1940-41	1,220
1929-30	3,290	1935-36	3,080	1941-42	2,640
1930-31	3,720	1936-37	1,800	1942-43	2,260
1931-32	3,380	1937-38	2.030	1943-44	2,630
1932-33	4,000	1938-39	2,660	1944-45	2,370

Consumptive Use

In Table 40 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. In the City of Glendora, which lies entirely within the basin, industrial development is small. Natural vegetation growing on the little unused land is mostly moderately heavy brush.

TABLE 40. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN GLENDORA BASIN

Type of culture	*Unit consumptive use, feet*	*1932*		*1942*	
		Acres	*Acre-feet*	*Acres*	*Acre-feet*
Valley Area					
Garden and field	1.3	6	8	6	8
Avocado and citrus	1.9	2,586	4,913	2,597	4,934
Deciduous	1.7	69	117	22	37
Domestic and industrial	1.5	291	436	338	507
Unirrigated	----	369	----	358	----
29- and 21-year periods	1.4	----	----	----	501
11-year period	1.385	----	511	----	----
Subtotal	----	3.321	----	3,321	----
29- and 21-year periods	----	----	----	----	5,987
11-year period	----	----	5,985	----	----
Hill and Mountain Area					
Avocado and citrus	0.5[a]	237	118	237	118
Grand total		3,558	----	3,558	----
29- and 21-year periods	----	----	----	----	6,105
11-year period	----	----	6,103	----	----

[a] Difference between irrigated culture and natural vegetation.

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and hills, and runoff originating in precipitation on the overlying valley. It is estimated to average 1,320 acre-feet, 1,130 acre-feet and 1,190 acre-feet annually in the 29-, 21- and 11-year periods, respectively, as derived in Table 41.

A large part of the mountain water entering this basin is concentrated in Big and Little Dalton Creeks. Some regulation is secured in Big Dalton Reservoir, and spreading is resorted to on both streams. Below spreading grounds both streams flow approximately two and one-half miles across the basin. The channels of both are restricted as to width, and that of Little Dalton Creek is paved for about two-thirds of a mile through the City of Glendora. Some mountain inflow from directly north of the city is carried to the channel along paved streets. Other small intermittent streams from the mountains, between the city and Little Dalton Canyon, flow for considerable distances across the alluvium before entering the channel. Big Dalton Creek skirts the mountains to the east and the hills to the south, and is unpaved throughout.

Daily discharges of Big Dalton Creek at Station 4374, and of Little Dalton Creek at Stations 4363 and 4364, have been measured for the periods 1920-21 to date, and 1929-30 to date, respectively. Assuming that 15 second-feet is diverted to spreading from Big Dalton during all three periods, 10 second-feet from Little Dalton under present conditions and five second-feet during the 11-year period, and that, with respective discharges of five second-feet and two second-feet in Big and Little Dalton Creeks below spreading grounds, no water reaches the lower boundary of the basin, outflow of water from this source during each year of record is estimated, utilizing percolation curves. Using the relationship between this outflow and measured annual discharges at the gaging station, average annual outflow in the two streams, from water originating above the gaging stations during the 29- and 21-year periods, is estimated. It is further estimated that outflow originating below these gaging stations comprises 50 percent of inflow from directly tributary mountains and hills, and 7 percent of precipitation on valley area within the basin.

TABLE 41. SURFACE OUTFLOW FROM GLENDORA BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
Estimated, originating in			
Measured mountain streams	430	320	410
Other directly tributary mountains	430	350	330
Directly tributary hills	50	50	50
Precipitation on valley land	410	410	400
Total	1,320	1,130	1,190

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Excess

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual excess is 560 acre-feet, as derived in Table 42. If 29-year mean values are substituted in the table, the derived annual excess is 920 acre-feet.

TABLE 42. ESTIMATED ANNUAL EXCESS IN GLENDORA BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual rise in storage during base period	----	----	----	250
Items tending to increase the rise				
Precipitation	5,900	5,770	130	
Surface inflow	2,550	2,280	270	
Import	2,760	2,910	—150	
Subtotal to be added				250
Items tending to decrease the rise				
Consumptive use	6,100	6,100	0	
Surface outflow	1,130	1,190	—60	
Subtotal to be subtracted				—60
Excess				560

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must, in accordance with principles set forth in Chapter V, have averaged 3,420 acre-feet annually, as derived in Table 43.

TABLE 43. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM GLENDORA BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	5,770	
Surface inflow	2,280	
Import	2,910	
Subtotal		10,960
Increase in storage	250	
Water leaving basin on surface		
Surface outflow	1,190	
Consumptive use	6,100	
Subtotal		7,540
Subsurface Outflow—to Central San Gabriel Valley Area		3,420

WAY HILL BASIN (12)

Way Hill Basin is located in the northeasterly portion of San Gabriel Valley, and covers about 2.6 square miles. It is bounded on the west by Main San Gabriel Basin, on the north by Glendora Basin and Way Hill, and on the east and south by San Dimas Basin. Topography of virtually all of this basin is smooth, with uniform slope to the west at a little less than 100 feet per mile. Elevations above sea level in the valley range from 700 to 1,100 feet. Soils covering this basin are mostly lighter members of the Hanford series. Municipal development occupies about 13 percent of the area, about 65 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on the valley, inflow from 590 acres of mountains and 360 acres of hills directly tributary to the basin, and inflow on the surface from Foothill Basin, the greater part of the last named as flood flow in San Dimas Creek. Imported water provides a relatively large addition to the supply.

A considerable part of the surface inflow and precipitation flows out into Main San Gabriel Basin, together with some underflow, and water is exported in relatively small amount to Main San Gabriel and San Dimas Basins.

In this basin, long-time mean annual net supply under present conditions is greater than present annual demand, so an excess exists. Evaluation of items required * to estimate its amount, follows.

Inflow

Estimated annual surface inflow to the basin averages 780 acre-feet, 610 acre-feet and 400 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 44.

The estimate of 29-year mean annual inflow from 590 acres of mountains and 360 acres of hills directly tributary to the basin is based on the assumption that, if water is available, average consumptive use on mountain area is 19 inches and that on hill area 17 inches, inflow values however being never less than $8\frac{1}{2}$ percent of precipitation on mountains and $9\frac{1}{2}$ percent of that on hills. The 11-year value for mountains is estimated to be 0.78 times the 29-year mean, this being the ratio between 11- and 29-year mean discharge of San Gabriel River. That for hills is 0.98 times the 29-year mean, being proportional to precipitation on the area represented by the San Gabriel Valley Group. Corresponding ratios for the 21-year period are 0.83 for mountains and 1.00 for hills.†

A part of the surface outflow from Foothill Basin, that in San Dimas Creek, enters Way Hill Basin.

Subsurface inflow, other than that indicated by note in Table 44, is negligible.

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* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

† If runoff from hills is assumed to follow the same regimen as flow in San Gabriel River, average runoff from that source during the 21-year period is 60 acre-feet, and during the 11-year period 50 acre-feet.

TABLE 44. SURFACE INFLOW TO WAY HILL BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
From directly tributary mountains Estimated[a]	120	100	100
From directly tributary hills Estimated[a]	70	70	70
From other basins Foothill	590	440	230
Total	780	610	400

[a] Includes a relatively small amount of underflow.

Import

In Table 45 estimated values of imports of water for each year since 1927-28 are presented. There is no import of sewage. During the 11-year period, an annual average of 1,200 acre-feet was imported from Main San Gabriel, Glendora and San Dimas Basins. Estimated average annual import of water under present conditions is 1,540 acre-feet, equal to the average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 45. IMPORT TO WAY HILL BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	740	1933-34	1,470	1939-40	1,180
1928-29	940	1934-35	980	1940-41	1,120
1929-30	1,300	1935-36	1,210	1941-42	1,400
1930-31	1,380	1936-37	1,280	1942-43	1,600
1931-32	1,240	1937-38	1,440	1943-44	1,640
1932-33	1,210	1938-39	1,360	1944-45	1,520

Consumptive Use

In Table 46 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. Domestic development is scattered over the basin, and industrial development is negligible. Natural vegetation, growing on the relatively little remaining unused land, is largely light brush, weeds and grass.

TABLE 46. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN WAY HILL BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley area					
Garden and field	1.3	13	17	31	40
Avocado and citrus	1.9	1,026	1,949	1,059	2,012
Deciduous	1.7	5	8	5	8
Irrigated grass	3.0	10	30	0	0
Domestic and industrial	1.5	161	242	223	334
Unirrigated	----	468	----	365	----
29- and 21-year periods	1.3	----	----	----	474
11-year period	1.286	----	602	----	----
Subtotal	----	1,683	----	1,683	----
29- and 21-year periods	----	----	----	----	2,868
11-year period	----	----	2,848	----	----
Hill and Mountain area					
Avocado and citrus	0.5[a]	52	26	52	26
Grand total	----	1,735	----	1,735	----
29- and 21-year periods	----	----	----	----	2,894
11-year period	----	----	2,874	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 47 estimated exports of water to Main San Gabriel and San Dimas Basins for each year since 1927-28 are presented. There is no sewage outflow. During the 11-year period an annual average of 140 acre-feet of water was exported. Estimated average annual export under present conditions is 230 acre-feet, equal to the average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 47. EXPORT FROM WAY HILL BASIN

Year	Acre-feet	Year	Acre-feet	Year	Acre-feet
1927-28	120	1933-34	160	1939-40	170
1928-29	110	1934-35	120	1940-41	170
1929-30	160	1935-36	160	1941-42	150
1930-31	150	1936-37	140	1942-43	230
1931-32	140	1937-38	140	1943-44	220
1932-33	170	1938-39	170	1944-45	300

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and hills, part of that from Foothill Basin, and runoff originating in precipitation on the overlying valley.

Inflow from directly tributary mountains enters the valley at considerable distance from the point of outflow, and it is estimated that none reaches that point. Inflow from hills enters the valley nearer the point of outflow, and it is estimated that 75 percent of this, or an annual average of 50 acre-feet, flows out in all three periods. Inflow from Foothill Basin is largely regulated by operation of San Dimas Reservoir and Puddingstone Diversion, and estimated average annual outflow originating in that source is 60, 40 and 20 acre-feet for the 29-, 21- and 11-year periods, respectively. On the assumption that 5 percent of precipitation on the valley runs off, annual outflow from that source averages 140 acre-feet.

Estimated total mean annual surface outflow is 250, 230 and 210 acre-feet in the 29-, 21- and 11-year periods, respectively.

Excess

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual excess is 710 acre-feet, as derived in Table 48. If 29-year mean values are substituted in the table, the derived annual excess is 860 acre-feet.

TABLE 48. ESTIMATED ANNUAL EXCESS IN WAY HILL BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual rise in storage during base period				220
Items tending to increase the rise				
Precipitation	2,800	2,730	70	
Surface inflow	610	400	210	
Import	1,540	1,200	340	
Subtotal to be added				620
Items tending to decrease the rise				
Consumptive use	2,890	2,870	20	
Surface outflow	230	210	20	
Export	230	140	90	
Subtotal to be subtracted				130
Excess				710

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must, in accordance with principles set forth in Chapter V, have average 890 acre-feet annually, as derived in Table 49.

TABLE 49. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM WAY HILL BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	2,730	
Surface inflow	400	
Import	1,200	
Subtotal		4,330
Increase in storage	220	
Water leaving basin on surface		
Surface outflow	210	
Export	140	
Consumptive use	2,870	
Subtotal		3,440
SUBSURFACE OUTFLOW—To Central San Gabriel Valley Area		890

FOOTHILL BASIN (14)

Foothill Basin is located at the mouth of San Dimas Canyon in the extreme northeasterly corner of San Gabriel Valley, and covers about 1.9 square miles. It is bounded on the northwest, north and east by San Gabriel Mountains, and on the south by San Dimas Basin. Topography is irregular with slopes varying in direction from southwest to southeast, at rates ranging between 100 and 500 or more feet per mile. Elevations above sea level range between 1,100 and 1,800 feet. Soils are about half Ramona loam, and half Hanford and Yolo soils. There is no municipal development, about 42 percent of the area being devoted to agriculture, with 58 percent remaining in a more or less natural state.

The local water supply, utilized in part through diversion from San Dimas Creek, partially regulated in San Dimas Reservoir, and in part through pumping from ground water, originates in precipitation on the valley and inflow from 14,090 acres of mountains directly tributary to the basin. Imported water provides a relatively small addition to the supply.

A considerable part of the surface inflow and precipitation flows out into Way Hill and San Dimas Basins, together with some underflow into the latter, and water is exported in relatively large amount to San Dimas Basin.

In this basin long-time mean annual supply under present conditions is greater than present annual demand, but storage capacity through which this supply can be utilized is so limited that it is logical to assume that all excess flows out. Evaluation of items required to estimate the long-time mean amount of surface outflow follows.*

Inflow

Estimated annual surface inflow to the basin averages 4,420 acre-feet, 3,660 acre-feet and 3,190 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 50.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Flow in San Dimas Creek at Station 4425, was measured throughout the 11- and 21-year periods, and during a part of the 29-year period. The 29-year value is derived by comparison with San Gabriel River.

The estimates of 29-year mean annual inflow from the 2,430 acres of mountains directly tributary to the basin, and downstream from the gaging station at which above inflow was measured, is based on the assumption that, if water is available, average annual consumptive use is 21 inches, runoff however never being less than 7½ percent of precipitation. The 11-year value is estimated to be 0.78 times the 29-year mean, this being the ratio between 11- and 29-year mean discharge of San Gabriel River. The corresponding ratio for the 21-year period is 0.83.

Subsurface inflow, other than that indicated by note in Table 50, is negligible.

TABLE 50. SURFACE INFLOW TO FOOTHILL BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Measured during part of period	4,080 [a]	3,380 [a]	2,930 [b]
Estimated [c]	340	280	260
Total	4,420	3,660	3,190

[a] Based on measured discharge, corrected for change in storage in reservoir but not corrected for reservoir losses.
[b] Based on actual discharge, uncorrected for reservoir operation.
[c] Includes a relatively small amount of underflow.

Import

In Table 51 estimated values of imports of water for each year since 1927-28 are presented. There is no import of sewage. During the 11-year period an annual average of 120 acre-feet of water was imported from pumped sources in San Dimas Basin. Estimated average annual import under present conditions is 160 acre-feet, equal to the average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 51. IMPORT TO FOOTHILL BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	100	1933-34	130	1939-40	120
1928-29	140	1934-35	120	1940-41	120
1929-30	100	1935-36	120	1941-42	150
1930-31	110	1936-37	130	1942-43	160
1931-32	140	1937-38	130	1943-44	140
1932-33	150	1938-39	120	1944-45	170

Consumptive Use

In Table 52 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. There is no industrial and very little domestic development. Unused land is largely of irregular topography, or is subject to overflow by San Dimas Creek and is covered by brush of varying size and density.

TABLE 52. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN FOOTHILL BASIN

Type of culture	*Unit consumptive use, feet*	*1932 Acres*	*1932 Acre-feet*	*1942 Acres*	*1942 Acre-feet*
Valley area					
Avocado and citrus	1.9	469	891	519	986
Deciduous	1.7	7	12	0	0
Unirrigated	----	757	----	714	----
29- and 21-year periods	1.4	----	----	----	1,000
11-year period	1.385	----	1,048	----	----
Subtotal	----	1,233	----	1,233	----
29- and 21-year periods	----	----	----	----	1,986
11-year period	----	----	1,951	----	----
Mountain area					
Avocado and citrus	0.5 [a]	59	30	59	30
Grand total	----	1,292	----	1,292	----
29- and 21-year periods	----	----	----	----	2,016
11-year period	----	----	1,981	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 53 estimated exports of water for each year since 1927-28 are presented. There is no sewage outflow. During the 11-year period, an annual average of 560 acre-feet of water was exported to San Dimas Basin from gravity sources in San Dimas Canyon.

The amount of water exported depends upon the amount of gravity water available. It is estimated that long-time mean annual export under present conditions is 670 acre-feet, equal to the average for the 21-year period, for each year of which records are available.

TABLE 53. EXPORT FROM FOOTHILL BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	150	1933-34	180	1939-40	690
1928-29	340	1934-35	800	1940-41	1,290
1929-30	380	1935-36	460	1941-42	780
1930-31	230	1936-37	1,210	1942-43	1,600
1931-32	350	1937-38	1,870	1943-44	1,910
1932-33	210	1938-39	610	1944-45	1,570

Surface Outflow During 11-Year Period

Outflow on the surface includes part of the inflow from directly tributary mountains, and runoff originating in precipitation on the overlying valley. It is estimated to average 1,820 acre-feet annually during the 11-year period, as derived in Table 54.

The greater part of outflow, that in San Dimas Creek, has been measured at Puddingstone Diversion Dam since 1935-36. Discharge at Station 4425 has been measured since 1917-18, and diversions just below that station since 1913-14. From the relationship between discharge at Puddingstone Diversion Dam, and the difference between discharge and diversion at the upper station, established during years of record common to all, discharge at the lower station during the years between 1927-28 and the beginning of record there is estimated.

To estimate outflow from areas not tributary to Puddingstone Diversion Dam, it is assumed that 80 percent of inflow from mountains east of the creek, 50 percent of that from those to the west, and 6 percent of precipitation on valley land east of the creek flows out on the surface.

TABLE 54. AVERAGE ANNUAL SURFACE OUTFLOW FROM FOOTHILL BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

(Acre-feet)

Estimated, originating in	
San Dimas Creek and Puddingstone Diversion	1,550
Directly tributary mountains	180
Precipitation on valley land	90
Total	1,820

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must, in accordance with principles set forth in Chapter V, have averaged 1,080 acre-feet annually, as derived in Table 55.

TABLE 55. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM FOOTHILL BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	2,130	
Surface inflow	3,190	
Import	120	
Change in storage in basin	0	
Subtotal		5,440
Water leaving basin on surface		
Surface outflow	1,820	
Export	560	
Consumptive use	1,980	
Subtotal		4,360
SUBSURFACE OUTFLOW—to San Dimas Basin		1,080

Long-time Mean Surface Outflow

The hydrologic equation used in the preceding article applies equally well in any period. Since there is neither excess nor overdraft in Foothill Basin, net change in storage over a cycle of long-time mean supply is zero.

Assuming that subsurface outflow is the same in all periods, all items involved other than surface outflow have been evaluated for both 29- and 21-year cycles. If the 21-year period is assumed to represent the cycle of long-time mean supply, long-time mean annual surface outflow is 2,230 acre-feet, as derived in Table 56. If the 29-year period is so considered, the value is 2,990 acre-feet.

TABLE 56. ESTIMATED LONG-TIME MEAN ANNUAL SURFACE OUTFLOW FROM FOOTHILL BASIN ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

	Acre-feet	
Supply to basin		
Precipitation	2,180	
Surface inflow	3,660	
Import	160	
Subtotal		6,000
Demand on basin other than surface outflow		
Consumptive use	2,020	
Export	670	
Subsurface outflow	1,080	
Subtotal		3,770
SURFACE OUTFLOW		2,230

SAN DIMAS BASIN (13)

San Dimas Basin is located in the easterly portion of San Gabriel Valley, and covers about 7.4 square miles. It is bounded on the west by Main San Gabriel Basin, on the north by Way Hill and Foothill Basins, on the northeast by San Gabriel Mountains, and on the southeast by Live Oak Basin and San Jose Hills. Topography of a large part of this basin is irregular because of several deeply incised barrancas which cut across it. Slope is generally to the southwest, and over most of the area averages a little less than 100 feet per mile. Lateral slopes in arroyos are much steeper. Elevations above sea level range from 650 to 1,225 feet. Soils covering the northerly half of this basin are lighter members of the Hanford series, and are quite receptive of moisture. Ramona loam, a little less pervious, covers the lower, southerly half. About 6 percent of the area is covered by culture of a municipal type, about 89 percent is devoted to agriculture, and only about 5 percent is still in a more or less natural state.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on the valley, inflow from 110 acres of mountains and 4,290 acres of hills directly tributary to the basin, inflow on the surface from Foothill and Pomona Basins, and inflow underground from Foothill Basin, the greater part of the surface inflow being in Puddingstone Diversion from San Dimas Creek. Imported water provides a relatively large addition to the supply.

A considerable part of the precipitation flows out into Main San Gabriel Basin together with some underflow. Most of the surface inflow is stored in Puddingstone Reservoir. A relatively large amount is exported to Way Hill and Foothill Basins, and a lesser amount to Pomona and Glendora Basins.

In this basin, long-time mean annual net supply under present conditions is somewhat greater than present annual demand, so a slight excess exists. Evaluation of items required* to estimate its amount follows.

Inflow

Estimated annual surface inflow to the basin averages 3,620 acre-feet, 3,000 acre-feet and 2,780 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 57.

The estimate of 29-year mean annual inflow from 110 acres of mountains directly tributary to the basin is based on the assumption that average annual consumptive use on mountain area is 18 inches. Inflow from 4,140 acres of hill area is estimated to be 10 percent of precipitation on the hills. Average inflow from mountains during the 11-year base period is estimated to be 0.78 times the 29-year mean, this being the ratio between 11- and 29-year mean discharge of San Gabriel River. The corresponding ratio for the 21-year period is 0.83.†

Inflow on the surface from other basins includes a part of surface outflow from Foothill and Pomona Basins. Subsurface inflow from Foothill Basin averages 1,080 acre-feet annually.

TABLE 57. SURFACE INFLOW TO SAN DIMAS BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Estimated [a]	20	20	20
From directly tributary hills			
Estimated [a]	620	620	610
Rainfall on Puddingstone Reservoir			
Estimated	230	230	230
From other basins			
Pomona	360[b]	350	320
Foothill	2,390	1,780	1,600
Total	3,620	3,000	2,780

[a] Includes a relatively small amount of underflow.
[b] Mean annual inflow during 32-year period, 1904-05 to 1935-36, inclusive.

Import

In Table 58 estimated values of imports of water for each year since 1927-28 are presented. There is no import of sewage. Water is imported from Main San Gabriel, Foothill, Pomona, Way Hill, and Live Oak Basins, and from Colorado River, and is derived from both gravity and pumped sources. During the 11-year period an annual average of 3,500 acre-feet was imported.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

† If inflow from hills is assumed to follow the same regimen as flow in San Gabriel River, average annual values of inflow from that source during the 21- and 11-year periods are 510 and 480 acre-feet, respectively.

Annual import from Colorado River, including only water used in and around the Metropolitan Water District Water Softening and Filtration plant, is assumed to equal the 1944-45 value. The average annual amount received from gravity diversion in San Dimas Canyon is estimated to equal its historic 21-year average. Average import from Pomona Basin by one entity is assumed to equal one-half the amount which it is permitted to pump there, since amount imported in any one year varies inversely with the gravity supply available to the entity. Average annual import from other sources is assumed to equal the average for the four-year period, 1941-42 to 1944-45, inclusive, except in the case of water imported from Main San Gabriel Basin for purely domestic use, which is assumed equal to the present pumping right there. Estimated average annual import under present conditions totals 5,250 acre-feet.

TABLE 58. IMPORT TO SAN DIMAS BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	2,360	1933-34	3,670	1939-40	2,120
1928-29	2,940	1934-35	3,310	1940-41	3,060
1929-30	3,350	1935-36	4,080	1941-42	3,060
1930-31	3,780	1936-37	3,430	1942-43	4,420
1931-32	3,760	1937-38	3,990	1943-44	4,980
1932-33	3,850	1938-39	2,400	1944-45	5,400

Consumptive Use

In Table 59 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. In addition to consumptive use so derived, it is estimated that evaporation from Puddingstone Reservoir averages 410 acre-feet annually during the 29-year period, 320 acre-feet in the 21-year, and 220 acre-feet in the 11-year period. A large part of the domestic culture is within the City of San Dimas. Industrial development is negligible. Natural vegetation on the little unused land ranges from moderately heavy brush to weeds and grass.

TABLE 59. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN SAN DIMAS BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley area					
Garden and field	1.3	7	9	25	32
Avocado and citrus	1.9	4,228	8,033	4,219	8,016
Deciduous	1.7	22	37	22	37
Irrigated grass	3.0	3	9	3	9
Domestic and industrial	1.5	245	368	263	394
Unirrigated	----	263	----	236	----
29- and 21-year periods	1.3	----	----	----	307
11-year period	1.286	----	338	----	----
Subtotal	----	4,768	----	4,768	--
29- and 21-year periods	----	----	----	----	8,795
11-year period	----	----	8,794	----	----
Hill and mountain area					
Garden and field	0.0*	1	0	1	0
Avocado and citrus	0.5*	177	88	177	88
Deciduous	0.3*	7	2	7	2
Domestic and industrial	0.1*	7	1	7	1
Subtotal	----	192	91	192	91
Grand total	----	4,960	----	4,960	----
29- and 21-year period	----	----	----	----	8,886
11-year period	----	----	8,885	----	----

* Difference between irrigated culture and natural vegetation.

Export

In Table 60 estimated exports of water and sewage for each year since 1927-28 are presented. Water is exported to Glendora, Way Hill, Foothill, Live Oak and Pomona Basins, while filtration plant waste which is considered sewage goes directly to the ocean. During the 11-year period, an annual average of 1,000 acre-feet of water was exported. Export of sewage did not start until 1940-41.

Estimated average annual export of water under present conditions is 960 acre-feet, and of sewage 1,370 acre-feet, a total of 2,330 acre-feet. It is assumed that 1944-45 sewage outflow and average annual export of water during the four-year period, 1941-42 to 1944-45, inclusive, represent present average annual export.

TABLE 60. EXPORT FROM SAN DIMAS BASIN

(Acre-feet)

Year	Water	Sewage[a]	Year	Water	Sewage[a]
1927-28	880	0	1936-37	660	0
1928-29	1,040	0	1937-38	780	0
1929-30	1,240	0	1938-39	700	0
1930-31	1,120	0	1939-40	780	0
1931-32	1,080	0	1940-41	740	400
1932-33	1,120	0	1941-42	950	550
1933-34	1,230	0	1942-43	900	700
1934-35	1,000	0	1943-44	1,020	890
1935-36	900	0	1944-45	960	1,370

[a] Waste from Metropolitan Water District Water Softening and Filtration Plant.

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and hills, part of that from Pomona and Foothill Basins, and runoff originating in precipitation on the overlying valley. It is estimated to average 1,210 acre-feet annually in the 29-year period, and 1,130 acre-feet in both the 21- and 11-year periods, as derived in Table 61.

Inflow from mountains directly tributary to the basin, as well as the greater part of the inflow from Pomona and Foothill Basins, and runoff originating in precipitation on the easterly one-fourth of San Dimas Basin, is subject to storage and regulation in Puddingstone Reservoir. Twenty-nine- and 21-year average annual outflow from this source is estimated by assuming a combined irrigation draft from San Dimas Creek and Puddingstone Reservoir of 3,900 acre-feet annually, with a maximum of 3,000 acre-feet from the reservoir, and annual carry-over storage limited to 7,000 acre-feet, and finally that 90 percent of resulting outflow from the reservoir reaches the lower boundary of the basin.

Outflow originating in other sources is estimated by assuming that 90 percent of runoff from directly tributary hills draining in below the reservoir, and 5 percent of the precipitation on the overlying valley, leaves the basin.

TABLE 61. SURFACE OUTFLOW FROM SAN DIMAS BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	29-year period	21-year period	11-year period
Estimated, originating in			
Release from Puddingstone Reservoir	550	470	480[a]
Directly tributary hills	380	380	370
Precipitation on valley land	280	280	280
Total	1,210	1,130	1,130

[a] Includes some evaporation loss from reservoir.

Excess

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual excess is 810 acre-feet, as derived in Table 62. If the 29-year mean values are substituted in the table, the derived annual excess is 1,260 acre-feet.

TABLE 62. ESTIMATED ANNUAL EXCESS IN SAN DIMAS BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual rise in storage during base period	----	----	----	110
Items tending to increase the rise				
Precipitation	7,800	7,630	170	
Surface inflow	3,000	2,780	220	
Import	5,250	3,500	1,750	
Subtotal to be added				2,140
Items tending to decrease the rise				
Evaporation from Puddingstone Reservoir	320	220[a]	100	
Consumptive use	8,890	8,880	10	
Surface outflow	1,130	1,130[a]	0	
Export	2,330	1,000	1,330	
Subtotal to be subtracted				1,440
EXCESS				810

[a] Outflow value includes some evaporation loss from Puddingstone Reservoir during 11-year period.

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must, in accordance with principles set forth in Chapter V, have averaged 3,650 acre-feet annually, as derived in Table 63.

TABLE 63. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM SAN DIMAS BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	7,630	
Surface inflow	2,780	
Import	3,500	
Subsurface inflow	1,080	
Subtotal		14,990
Increase in storage	110[a]	
Water leaving basin on surface		
Surface outflow	1,130[b]	
Export	1,000	
Evaporation from Puddingstone Reservoir	220[b]	
Consumptive use	8,880	
Subtotal		11,340
SUBSURFACE OUTFLOW—to Central San Gabriel Valley Area		3,650

[a] Includes 770 acre-feet going into storage in Puddingstone Reservoir.
[b] Outflow value includes some of the evaporation loss from reservoir.

SPADRA BASIN (30)

Spadra Basin is located in the extreme west portion of Upper Santa Ana Valley, and covers about 6.6 square miles. It is bounded on the northwest and north by San Jose Hills, on the east by Chino Basin, on the south and southeast by Puente Hills, and on the southwest by Puente Basin. Topography is irregular, with average slope to the west and southwest of about 55 feet per mile. Elevations above sea level range from 625 to 920 feet. Soils covering the basin are about equally divided between light Hanford soils, and heavier soils of the Chino series. In San Jose Valley the latter predominate. Municipal development occupies about 16 percent of the area, about 63 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized through pumping from ground water originates in precipitation on the valley, inflow from 3,820 acres of hills directly tributary to the basin, subsurface inflow from Chino Basin, and inflow on the surface from Pomona Basin, the greater part of the last named as flood flow in San Jose Creek. Imported water provides some addition to the supply.

A considerable part of surface inflow and precipitation flows out into Puente Basin, together with some underflow. Sewage is exported for use in the same basin.

In this basin, long-time mean annual net supply under present conditions is less than present annual demand, so an overdraft exists. Evaluation of items required * to estimate its amount follows.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

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Inflow

Estimated annual surface inflow to the basin averages 950 acre-feet, 940 acre-feet and 920 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 64. The estimate of inflow from 3,820 acres of directly tributary hills is based on the assumption that 9 percent of precipitation on hills runs off.* A part of the surface outflow from Pomona Basin enters Spadra Basin.

Estimated subsurface inflow from Chino Basin averages 710 acre-feet annually.

TABLE 64. SURFACE INFLOW TO SPADRA BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
From directly tributary hills			
Estimated [a]	500	500	490
From other basins			
Pomona	450 [b]	440	430
Total	950	940	920

[a] Includes a relatively small amount of underflow.
[b] 32-year mean value.

Import

In Table 65 estimated values of imports of water from pumped sources in Pomona Basin for each year since 1927-28 are presented. During the 11-year period it averaged 1,370 acre-feet annually.

Estimated average annual import under present conditions is 1,800 acre-feet, equal to the historic average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 65. IMPORT TO SPADRA BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	1,880	1933-34	1,260	1939-40	1,910
1928-29	1,760	1934-35	1,130	1940-41	1,760
1929-30	1,600	1935-36	1,290	1941-42	1,600
1930-31	1,440	1936-37	1,060	1942-43	1,920
1931-32	1,320	1937-38	1,100	1943-44	1,920
1932-33	1,270	1938-39	1,460	1944-45	1,750

Consumptive Use

In Table 66 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. A portion of the City of Pomona overlies the basin. Various agricultural crops are distributed over the area. The relatively small area of unirrigated land is covered largely by grass and weeds.

* If runoff from hills is assumed to follow the same regimen of flow as San Gabriel River, average annual inflow from that source is 420 and 390 acre-feet for the 21- and 11-year periods, respectively.

TABLE 66. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN SPADRA BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley area					
Garden and field	1.3	259	337	225	292
Avocado and citrus	2.0	837	1,674	842	1,684
Deciduous	1.8	1,504	2,707	1,429	2,572
Alfalfa	3.0	5	15	138	414
Irrigated grass	3.0	29	87	29	87
Domestic and industrial	1.8	637	1,147	692	1,246
Unirrigated	----	966	----	882	----
29- and 21-year periods	1.3	----	----	----	1,147
11-year period	1.286	----	1,242	----	----
Subtotal	----	4,237	----	4,237	----
29- and 21-year periods	----	----	----	----	7,442
11-year period	----	----	7,209	----	----
Hill area					
Avocado and citrus	0.7[a]	12	8	12	8
Deciduous	0.5[a]	15	8	15	8
Irrigated grass	1.7[a]	104	177	104	177
Domestic and industrial	0.4[a]	24	10	44	18
Subtotal	----	155	203	175	211
Grand total	----	4,392	----	4,412	----
29- and 21-year periods	----	----	----	----	7,653
11-year period	----	----	7,412	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 67 estimated values of exports of sewage to Puente Basin for each year since 1927-28 are presented. No water is exported. During the 11-year period export of sewage averaged 200 acre-feet annually.

Average annual export of sewage under present conditions is assumed equal to the 1944-45 value, or 510 acre-feet.

TABLE 67. EXPORT FROM SPADRA BASIN

(Acre-feet)

Year	Sewage	Year	Sewage	Year	Sewage
1927-28	—370	1933-34	250	1939-40	340
1928-29	180	1934-35	280	1940-41	360
1929-30	180	1935-36	290	1941-42	410
1930-31	240	1936-37	330	1942-43	480
1931-32	240	1937-38	330	1943-44	510
1932-33	230	1938-39	330	1944-45	510

Surface Outflow

Surface outflow includes part of the inflow from directly tributary hills, part of that from Pomona Basin and runoff originating in precipitation on the overlying valley. It is estimated to average 1,240 acre-feet annually in the 29- and 21-year periods, and 1,210 acre-feet in the 11-year period, as derived in Table 68.

Inflow from directly tributary hills is distributed throughout the length of the basin. That from the north enters San Jose Wash, which rounds the easterly point of San Jose Hills out of Pomona Basin and traverses Spadra Basin for about five miles, roughly paralleling the northwesterly edge of the valley at a distance of about one-half mile. Inflow from Puente Hills on the south enters San Jose Creek directly. This stream lies approximately one-half mile southeast of and parallel to San Jose Wash, and joins it just below the Spadra-Puente Basin boundary. Neither stream is paved, but width of San Jose Wash is restricted by bank protection.

Estimated surface outflow includes 80 percent of inflow from directly tributary hills, 90 percent of surface inflow from Pomona Basin, and 7 percent of precipitation on valley area within the basin.*

TABLE 68. SURFACE OUTFLOW FROM SPADRA BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
Estimated, originating in			
Directly tributary hills	400	400	390
Inflow from other basins	400	400	390
Precipitation on valley land	440	440	430
Total	1,240	1,240	1,210

Overdraft

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual overdraft is 830 acre-feet, as derived in Table 69. If 29-year mean values are substituted in the table the derived value is 820 acre-feet.

* Measured discharge at Station 2977 is used as a guide in determining the percentages.

TABLE 69. ESTIMATED ANNUAL OVERDRAFT IN SPADRA BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period	----	----	----	840
Items tending to increase the drop				
Consumptive use	7,650	7,410	240	
Export	510	200	310	
Surface outflow	1,240	1,210	30	
Subtotal to be added				580
Items tending to decrease the drop				
Precipitation	6,270	6,130	140	
Surface inflow	940	920	20	
Import	1,800	1,370	430	
Subtotal to be subtracted				590
OVERDRAFT				830

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year period must, in accordance with principles set forth in Chapter V, have averaged 1,150 acre-feet annually, as derived in Table 70.

TABLE 70. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM SPADRA BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	6,130	
Surface inflow	920	
Import	1,370	
Subsurface inflow	710	
Water coming from storage in basin	840	
Subtotal		9,970
Water leaving basin on surface		
Surface outflow	1,210	
Exported sewage	200	
Consumptive use	7,410	
Subtotal		8,820
SUBSURFACE OUTFLOW—to Puente Basin		1,150

PUENTE BASIN (15)

Puente Basin occupies the lower portion of San Jose Valley, a southeasterly extension of San Gabriel Valley, and covers about 20 square miles. It is bounded on the southwest, south and southeast by Puente Hills, on the north and northwest by Main San Gabriel Basin and San Jose Hills, and on the northeast by Spadra Basin. Lines of contact between valley and hill lands, both to the north and south, are very irregular. Slopes downward from the hills are generally toward San Jose Creek, which traverses the length of the valley, and vary greatly both in steepness and direction. Slope down the axis of the valley averages about 30 feet per mile. Elevations in the valley range between 290 and 975 feet above sea level. Soils are mostly heavier members of the Chino series, and the somewhat lighter and more pervious Yolo loam. About 3 percent of the area is covered by culture of a municipal type, about 68 per cent is devoted to agriculture, and about 29 percent is in a more or less natural state.

The local water supply, utilized almost entirely through pumping from ground water, originates in precipitation on valley land, inflow from 17,280 acres of hills directly tributary to the basin, and inflow both underground and on the surface from Spadra Basin, the greater part of the last named as flood flow in San Jose Creek. Imported water and sewage provide a relatively large addition to the supply.

A considerable part of surface inflow and precipitation flows out into Main San Gabriel Basin, together with comparatively large underflow. There is no export of water or sewage.

In this basin, long-time mean annual net supply under present conditions is a little greater than present annual demand, so a small excess exists. Evaluation of items required * to estimate its amount follows.

Inflow

Estimated annual surface inflow to the basin averages 3,830 acre-feet in the 29- and 21-year periods and 3,750 acre-feet during the 11-year period, as derived in Table 71. The estimate of inflow from 17,280 acres of hills directly tributary to the basin is based on the assumption that 10 percent of precipitation on hills runs off.†

All surface and subsurface outflow from Spadra Basin enters Puente Basin. Estimated subsurface inflow from this source during the 11-year period averages 1,150 acre-feet annually.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

† If inflow from hills is assumed to follow the same regimen of flow as San Gabriel River, average inflow during the 21-year period is 2,150 acre-feet annually, and during the 11-year period, 2,020 acre-feet.

TABLE 71. SURFACE INFLOW TO PUENTE BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
From directly tributary hills			
Estimated [a]	2,590	2,590	2,540
From other basins			
Spadra	1,240	1,240	1,210
Total [a]	3,830	3,830	3,750

[a] Includes a relatively small amount of underflow.

Import

In Table 72 estimated values of imports of water and sewage for each year since 1927-28 are presented. Water is imported from pumped sources in Main San Gabriel Basin and from Colorado River, while sewage inflow is from Chino, Pomona and Spadra Basins. During the 11-year period, an annual average of 2,900 acre-feet of water, and 1,120 acre-feet of sewage was imported, a total of 4,020 acre-feet.

It is estimated that average annual import of water under present conditions is 3,280 acre-feet, and of sewage, 2,360 acre-feet, a total of 5,640 acre-feet. The 1944-45 import of Colorado River water and of sewage, and the annual average import of other water during the four-year period, 1941-42 to 1944-45, inclusive, are assumed to constitute the average under present conditions.

TABLE 72. IMPORT TO PUENTE BASIN

(Acre-feet)

Year	*Water*	*Sewage*	*Year*	*Water*	*Sewage*
1927-28	2,620	340	1936-37	2,900	1,500
1928-29	2,620	980	1937-38	2,970	1,480
1929-30	2,920	980	1938-39	3,210	1,480
1930-31	3,170	1,120	1939-40	2,520	1,530
1931-32	3,010	1,130	1940-41	2,550	1,640
1932-33	2,910	1,060	1941-42	2,710	1,870
1933-34	3,290	1,130	1942-43	3,390	2,240
1934-35	2,230	1,300	1943-44	3,370	2,360
1935-36	3,280	1,310	1944-45	3,300	2,360

Consumptive Use

In Table 73 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. Domestic use is small, as is industrial development. Citrus occupies much of the higher ground, with other crops intermingled in the valley. Natural vegetation growing on unused land is largely weeds and grass, with a few small areas of water-loving trees and brush along San Jose Creek.

TABLE 73. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN PUENTE BASIN

Type of culture	*Unit consumptive use, feet*	*1932* *Acres*	*1932* *Acre-feet*	*1942* *Acres*	*1942* *Acre-feet*
Valley and folded area					
Garden and field	1.3	374	486	483	628
Avocado and citrus	1.9	3,831	7,279	4,037	7,670
Deciduous	1.7	4,305	7,318	3,774	6,416
Alfalfa	3.0	233	699	572	1,716
Domestic and industrial	1.5	282	423	334	501
Unirrigated	----	4,001	----	3,826	----
29- and 21-year periods	1.2	----	----	----	4,591
11-year period	1.187	----	4,749	----	----
Subtotal	----	13,026	----	13,026	----
29- and 21-year periods	----	----	----	----	21,522
11-year period	----	----	20,954	----	----
Hill area					
Garden and field	0[a]	47	0	37	0
Avocado and citrus	0.5[a]	696	348	754	377
Deciduous	0.3[a]	74	22	84	25
Alfalfa	1.6[a]	3	5	13	21
Subtotal	----	820	375	888	423
Grand total	----	13,846	----	13,914	----
29- and 21-year periods	----	----	----	----	21,945
11-year period	----	----	21,329	----	----

[a] Difference between irrigated culture and natural vegetation.

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary hills, part of that from Spadra Basin, and runoff originating in precipitation on the overlying valley. It is estimated to average 3,810 acre-feet annually in both the 29- and 21-year periods and 3,730 acre-feet in the 11-year period, as derived in Table 74.

Inflow from San Jose Hills on the north is well distributed in many small streams, and enters San Jose Creek soon after emerging from the hills. That from Puente Hills, also well distributed, flows for an average of two miles before reaching the channel. A part of this flow is along paved roads. The unpaved channel of San Jose Creek is 11 miles long within the basin. In some places water table and channel bed coincide, while elsewhere percolation occurs. Inflow from Spadra Basin is in San Jose Wash and San Jose Creek, which join just after entering Puente Basin. It is estimated that outflow* includes 75 percent of inflow from directly tributary hills, 75 percent of inflow from Spadra Basin, and 5 percent of precipitation on overlying valley land.*

* Measured discharge at Station 2977 is used as a guide in determining percentages.

TABLE 74. SURFACE OUTFLOW FROM PUENTE BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
Estimated, originating in			
Directly tributary hills	1,940	1,940	1,900
Inflow from other basins	930	930	910
Precipitation on valley and folded land	940	940	920
Total	3,810	3,810	3,730

Excess

Assuming that either the 21- or 29-year period is the cycle of long-time mean supply, estimated annual excess is 1,080 acre-feet, as derived in Table 75.

The City of Puente and surrounding area is included in Los Angeles County Sanitation District No. 15, recently formed. As sewer systems are installed in the area, and sewage exported to the ocean, indicated excess for present conditions will be decreased or eliminated entirely by the sewage outflow.

TABLE 75. ESTIMATED ANNUAL EXCESS IN PUENTE BASIN UNDER PRESENT CONDITIONS, ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period	----	----	----	340
Items tending to increase the drop				
Consumptive use	21,940	21,330	610	
Surface outflow	3,810	3,730	80	
Subtotal to be added				690
Items tending to decrease the drop				
Precipitation	18,950	18,540	410	
Surface inflow	3,830	3,750	80	
Import	5,640	4,020	1,620	
Subtotal to be subtracted				2,110
EXCESS				1,080

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period must, in accordance with principles set forth in Chapter V, have averaged 2,740 acre-feet annually, as derived in Table 76.

TABLE 76. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM PUENTE BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	18,540	
Surface inflow	3,750	
Imported water	2,900	
Imported sewage	1,120	
Subsurface inflow	1,150	
Water coming from storage in basin	340	
Subtotal		27,800
Water leaving basin on surface		
Surface outflow	3,730	
Consumptive use	21,330	
Subtotal		25,060
SUBSURFACE OUTFLOW—to Central San Gabriel Valley Area		2,740

CENTRAL SAN GABRIEL VALLEY AREA

Main San Gabriel Basin (6)
Upper Canyon Basin (9)
Lower Canyon Basin (10)

While effective barriers separate these three basins, they operate as a unit and are therefore combined in this discussion. They occupy all the central portion of San Gabriel Valley, and cover about 124 square miles. The area is bounded on the north by San Gabriel Mountains and Raymond Fault, beyond which lies Raymond Basin Area, on the east by Glendora, Way Hill and San Dimas Basins, on the southeast by San Jose Hills, on the south by Puente Basin and Puente Hills, and on the southwest and west by Merced Hills, San Rafael Hills and Whittier Narrows, beyond which lies Montebello Forebay Area. Topography is relatively smooth throughout. In the upper outwash area of San Gabriel River the surface is cut by innumerable shallow channels, ditches and other depressions. Slope is generally toward Whittier Narrows. Near the Narrows it averages 20 feet per mile, and gradually increases to 75 feet per mile near Azusa, and 125 feet per mile in the Monrovia-Duarte area. Debris cones of San Gabriel River, and of groups of smaller streams both to the east and west, are well defined almost to the Narrows. Elevations above sea level range from 200 feet at the Narrows, to 800 feet near Monrovia and 900 feet in the vicinity of Glendora. Soils are mostly lighter members of the Hanford series, with a few areas of still more open Tujunga soils along San Gabriel River. In the area lying west of Eaton

Wash, somewhat heavier Ramona soils predominate, while below El Monte in the zone of rising water there are considerable areas of Chino soils. Municipal development occupies about 35 percent of the area, about 41 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized to a considerable extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on valley lands, inflow from 242 square miles of mountains and 5,530 acres of hills directly tributary to the basin, and inflow both underground and on the surface from Raymond Basin Area, and from Glendora, Way Hill, San Dimas and Puente Basins. San Gabriel River is by far the largest stream discharging into the area. Imported water provides a relatively small addition to the supply. Sewage is imported from Western Unit of Raymond Basin Area and from Los Angeles Narrows Basin.

A considerable part of surface inflow and precipitation flows out into Montebello Forebay Area, together with comparatively large underflow, and water is exported in relatively large amount to La Habra and Puente Basins and to Montebello Forebay Area, and in less amount to Glendora, Way Hill, San Dimas and Los Angeles Narrows Basins. During the period, 1933-34 through 1940-41, export to Western Unit of Raymond Basin Area was large, but at present it is very small. Sewage outflow, the greater part of it in Rio Hondo, is relatively large.

As demonstrated by the comparison depicted on Plate 24, Main San Gabriel Basin, the downstream member of this group, is one in which outflow of rising water responds quickly to changes in elevation of the water table. Where this is true, neither excess nor overdraft is considered to exist. Supply to Upper and Lower Canyon Basins is so large, and their carry-over storage capacity so small, that it is assumed that there too neither overdraft nor excess exists. Main San Gabriel Basin serves as a partial regulator of supply to the area below Whittier Narrows, so long-time mean surface outflow to Montebello Forebay Area under present conditions is the value herein estimated. Evaluation of items required* to estimate its amount follows.

Inflow

Estimated annual surface inflow to the area averages 155,700 acre-feet, 131,370 acre-feet and 122,600 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 77.

Inflow from directly tributary mountains above gaging stations at which flow was measured during all or part of each period is tabulated below. Twenty-nine year values for Fish, Rogers and Sawpit Creeks are derived by comparison with San Gabriel River. The evaporation loss shown is that from three mountain reservoirs on San Gabriel River.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Stream	Station	Mean annual inflow in acre-feet 29-year period	21-year period	11-year period
San Gabriel River	4294, 4313	130,900[a]	108,010[a]	99,030[b]
Rogers Creek	4293	2,770	2,470	2,060
Fish Creek	4273	3,730	3,410	3,080
Sawpit Creek	4202	2,330[a]	2,080[a]	1,680[b]
Subtotal		139,730	115,970	105,850
Estimated evaporation from San Gabriel River Reservoirs		2,200	2,200	
Remainder		137,530	113,770	105,850

[a] Full natural flow as reconstructed, corrected for reservoir operation.
[b] Actual inflow including diversions, but not corrected for reservoir operation.

The estimate of 29-year mean annual inflow from 6,230 acres of mountains directly tributary to the area, and downstream from gaging stations at which above inflow was measured, is based on the assumption that, if water is available, average annual consumptive use on mountain area is 20 inches, inflow however being never less than 8 percent of precipitation on the mountains. The 11-year value is estimated to be 0.78 times the 29-year mean, this being the ratio between 11- and 29-year mean discharge of San Gabriel River. The corresponding ratio for the 21-year period is 0.83. Estimated inflow from 5,530 acres of directly tributary hills is 10 percent of the precipitation thereon.*

Inflow on the surface from other basins includes all surface outflow from Eastern Unit of Raymond Basin Area, and from Glendora, Way Hill, San Dimas and Puente Basins, and part of that from Western Unit of Raymond Basin Area. Subsurface inflow, averaging 13,800 acre-feet annually during the 11-year period, includes underflow from Raymond Basin Area, and from Glendora, Way Hill, San Dimas and Puente Basins.

* If runoff from hills is assumed to follow the same regimen as flow in San Gabriel River, average annual runoff during 21- and 11-year periods is 670 and 630 acre-feet, respectively.

TABLE 77. INFLOW TO CENTRAL SAN GABRIEL VALLEY AREA

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
Surface Inflow			
From directly tributary mountains			
Measured during all or part of period	137,530	113,770	105,850
Estimated [a]	1,180	980	920
From directly tributary hills			
Estimated [a]	810	810	790
From other basins			
Western Unit of Raymond Basin Area	5,180	5,330	5,270
Eastern Unit of Raymond Basin Area	4,410	4,180	3,510
Glendora	1,320	1,130	1,190
Way Hill	250	230	210
San Dimas	1,210	1,130	1,130
Puente	3,810	3,810	3,730
Total	155,700	131,370	122,600
Subsurface inflow from other basins			
Western Unit of Raymond Basin Area	----	----	2,860
Eastern Unit of Raymond Basin Area	----	----	240
Glendora	----	----	3,420
Way Hill	----	----	890
San Dimas	----	----	3,650
Puente	----	----	2,740
Total			13,800

[a] Includes a relatively small amount of underflow.

Import

In Table 78 estimated values of imports of water and sewage for each year since 1927-28 are presented. Water is imported from Eastern and Western Units of Raymond Basin Area, from Montebello Forebay Area, and from Way Hill, Pomona and Los Angeles Narrows Basins, while sewage inflow is from Western Unit of Raymond Basin Area and Los Angeles Narrows Basin. During the 11-year period an annual average of 12,650 acre-feet of water and 5,600 acre-feet of sewage was imported, a total of 18,250 acre-feet.

It is estimated that average annual import of water under present conditions is 8,000 acre-feet, and of sewage 7,780 acre-feet, a total of 15,780 acre-feet. Present import from Western Unit of Raymond Basin Area is based upon decreed rights of exporters from the Western Unit, use of water during 1944-45 in their service areas within the Unit, and amount released by them for Fiscal Year 1946-47 under the Water Exchange Agreement. Present annual import from Eastern Unit of Raymond Basin Area is the calculated amount available for export from said Unit without exceeding safe yield. Present annual import from Los Angeles Narrows Basin is assumed to be that of 1944-45. Present import from Pomona and Way Hill Basins and Montebello Forebay Area is assumed to equal the historic average for the four-year period, 1941-42 to 1944-45, inclusive. Present annual average sewage import is assumed to be that of 1944-45.

TABLE 78. IMPORT TO CENTRAL SAN GABRIEL VALLEY AREA

(Acre-feet)

Year	*Water*	*Sewage*	*Year*	*Water*	*Sewage*
1927-28	14,180	4,740	1936-37	11,510	6,200
1928-29	13,730	5,130	1937-38	11,320	6,380
1929-30	13,200	5,120	1938-39	11,380	6,560
1930-31	13,540	5,370	1939-40	12,120	6,670
1931-32	12,390	5,780	1940-41	11,990	6,990
1932-33	12,390	5,540	1941-42	13,260	6,840
1933-34	13,760	5,610	1942-43	14,300	7,050
1934-35	10,790	5,770	1943-44	13,900	7,470
1935-36	12,380	5,940	1944-45	9,990	7,780

Consumptive Use

In Table 79 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. The greater part of usable land in the area is occupied. Municipal development in the westerly portion of the area includes the cities of Alhambra, El Monte, Monterey Park, San Gabriel, San Marino, Arcadia, Monrovia, and some unincorporated communities. That in the easterly portion includes the Cities of Azusa and Covina, together with the unincorporated town of Baldwin Park. By far the largest part of the municipal development lies west of San Gabriel River. Industrial development is largely in the City of Alhambra, and while it materially increases the demand for water, the amount actually consumed is relatively small. Citrus occupies much of the higher ground, and alfalfa, garden and field crops are produced on the smooth, fine textured soils of lower lands. Natural vegetation is largely light brush and grass, with a considerable area of water-loving vegetation just above Whittier Narrows.

TABLE 79. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN CENTRAL SAN GABRIEL VALLEY AREA

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley and folded area					
Garden and field	1.3	8,379	10,893	8,028	10,436
Avocado and citrus	1.9	15,017	28,532	14,791	28,103
Deciduous	1.7	12,702	21,593	6,849	11,643
Alfalfa	3.0	1,546	4,638	1,986	5,958
Irrigated grass	3.0	474	1,422	854	2,562
Domestic and industrial	1.5	20,540	30,810	27,913	41,870
Natural water-loving vegetation	4.0	934	3,736	934	3,736
Unirrigated	----	19,990	----	18,227	----
29- and 21-year periods	1.2	----	----	----	21,872
11-year period	1.187	----	23,728	----	----
Subtotal	----	79,582	----	79,582	----
29- and 21-year periods	----	----	----	----	126,180
11-year period	----	----	125,352	----	----
Hill and mountain area					
Garden and field	0[a]	8	0	8	0
Avocado and citrus	0.6[a]	504	302	517	310
Deciduous	0.4[a]	34	14	34	14
Alfalfa	1.7[a]	5	8	5	8
Irrigated grass	1.7[a]	52	88	52	88
Domestic and industrial	0.2[a]	880	176	974	195
Subtotal	----	1,483	588	1,590	615
Grand total	----	81,065	----	81,172	----
29- and 21-year periods	----	----	----	----	126,795
11-year period	----	----	125,940	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 80, estimated exports of water and sewage for each year since 1927-28 are presented. Water is exported to Western Unit of Raymond Basin Area, to Montebello Forebay Area, and to Glendora, Way Hill, San Dimas, Puente, La Habra and Los Angeles Narrows Basins, while that part of the sewage which is herein treated as an export goes directly to the ocean. Flow through Whittier Narrows in various ditches, and sewage from the Tri-City plant and from El Monte which enters Rio Hondo above the Narrows, are treated as a part of the surface outflow rather than as exports. Water diverted at Morris Reservoir from 1933-34 to 1940-41, inclusive, for use in Raymond Basin Area is considered an export from Central San Gabriel Valley Area. During the 11-year period an annual average of 23,420 acre-feet of water and 830 acre-feet of sewage was exported, a total of 24,250 acre-feet.

It is estimated that average annual export of water under present conditions is 20,630 acre-feet, and of sewage 2,470 acre-feet, a total of 23,100 acre-feet. It is assumed that present export of water to Western Unit of Raymond Basin Area, and present sewage outflow are equal to their 1944-45 values. Present export to Glendora Basin is estimated to equal the historic annual average for the four-year period, 1941-42 to 1944-45, inclusive, *plus* the difference between average annual diversions from Big and Little Dalton Creeks for the four-year period, and for the 21-year period. Present export to Way Hill, Puente, La Habra and Los Angeles Narrows Basins and to Montebello Forebay Area is estimated to equal the annual average for the four-year period, 1941-42 to 1944-45, inclusive. Present export to San Dimas Basin for domestic purposes is assumed to equal the amount available under present arrangements, since demand for domestic water is increasing rapidly.

TABLE 80. EXPORT FROM CENTRAL SAN GABRIEL VALLEY AREA

(Acre-feet)

Year	*Water*	*Sewage*	*Year*	*Water*	*Sewage*
1927-28	17,000	670	1936-37	27,580	990
1928-29	18,730	750	1937-38	31,510	1,130
1929-30	20,500	790	1938-39	34,350	1,220
1930-31	22,320	780	1939-40	33,170	1,520
1931-32	21.830	790	1940-41	20,960	1,840
1932-33	23,040	790	1941-42	18,860	2,020
1933-34	28,130	730	1942-43	20,300	2,720
1934-35	22,470	830	1943-44	21,180	2,740
1935-36	24,490	840	1944-45	19,610	2,470

Surface Outflow During 11-Year Period

During the 11-year period by far the larger part of outflow from the area was measured at or near Whittier Narrows. Of this, an average annual discharge of 42,770 acre-feet was carried by Rio Hondo, 12,140 acre-feet by Rio Hondo Slough, and 37,010 acre-feet by San Gabriel River. The total included 37,540 acre-feet of rising water, approximately 8,000 acre-feet of effluent from the Tri-City Sewage Treatment Plant, a small amount not exceeding 700 acre-feet, came from City of El Monte sewage, and the remainder was runoff which flowed across Central San Gabriel Valley Area on the surface. A considerable part of the rising water is diverted just above the Narrows and carried through in ditches, but all is here treated as surface outflow.

In addition to measured flow, estimated average annual outflow includes 130 acre-feet of water originating in hills, and 630 acre-feet originating in precipitation on the valley, assuming that 10 percent of precipitation on the extreme westerly portion of the basin, 5 percent of that on remaining valley lands, and 90 percent of inflow from hills leaves the basin.

Estimated total average annual surface outflow during the 11-year period is 92,680 acre-feet.

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must, in accordance with principles set forth in Chapter V, have averaged 23,280 acre-feet annually, as derived in Table 81. In an analysis involving the use of measured rising water and water table slopes, James Kimble estimated the subsurface outflow at 23,170 acre-feet per year.* In an earlier study of San Gabriel Valley Water supply, the State Division of Water Rights used a value of 25,000 acre-feet.†

TABLE 81. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM CENTRAL SAN GABRIEL VALLEY AREA DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering area		
Precipitation	115,860	
Surface inflow	122,600	
Imported water	12,650	
Imported sewage	5,600	
Subsurface inflow	13,800	
Subtotal		270,510
Increase in storage	4,360	
Water leaving basin on surface		
Surface outflow	92,680	
Exported water	23,420	
Exported sewage	830	
Comsumptive use	125,940	
Subtotal		247,230
SUBSURFACE OUTFLOW—to Montebello Forebay Area		23,280

Long-time Mean Surface Outflow

The hydrologic equation used in the preceding article applies equally well in all periods. As has been stated, it is considered that neither overdraft nor excess exists. Long-time mean surface outflow, herein estimated, is that quantity which balances all other items involved.

Assuming the 21-year period to be one of long-time mean supply, estimated mean annual surface outflow is 106,200 acre-feet, as derived in Table 82. If 29-year mean values are substituted the derived outflow is 130,530 acre-feet.

Extensive sewerage improvements have recently been authorized, consisting of outfall lines to the ocean, and sewer systems for presently unsewered areas. As these are completed, long-time mean outflow will be decreased by the amount of increased sewage export and elimination of effective sewage import.

* American Geophysical Union, 1936, "Underflow at Whittier Narrows, etc."
† Bulletin No. 7, San Gabriel Investigation, 1928.

TABLE 82. ESTIMATED LONG-TIME MEAN ANNUAL SURFACE OUTFLOW FROM CENTRAL SAN GABRIEL VALLEY AREA ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

	Acre-feet	
Supply to area		
Precipitation	118,430	
Surface inflow	131,370	
Import	15,780	
Subsurface inflow	13,800	
Subtotal		279,380
Demand on area		
Consumptive use	126,800	
Export	23,100	
Subsurface outflow	23,280	
Subtotal		173,180
SURFACE OUTFLOW		106,200

LA HABRA BASIN (34)

La Habra Basin is located in the northeast portion of the Coastal Plain, and covers about 40 square miles. It is bounded on the west by Montebello Forebay Area, on the northeast and north by Puente Hills, on the east by Yorba Linda Basin, and on the south by Central Coastal Plain Pressure Area and Santa Ana Forebay Area. Topography is very irregular, with slopes generally to the south averaging about 150 feet per mile, but varying widely either way from this figure for short distances. Elevations above sea level range from 115 to 800 feet. Soils are mostly medium textured and heavy members of the Yolo and Ramona series, and are only moderately pervious. Municipal development occupies about 13 percent of the area, about 63 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized almost entirely through pumping from ground water, originates in precipitation on the overlying valley, inflow from 18,760 acres of hills directly tributary to the basin, and very small inflow on the surface from Montebello Forebay Area. Imported water provides a large addition to the supply.

A considerable part of the surface inflow and precipitation on the valley flows out into Central Coastal Plain Pressure Area and to Santa Ana Forebay Area, together with some underflow to Montebello Forebay Area. Water is exported in relatively large amount to Central Coastal Plain Pressure Area, and in lesser quantity to Yorba Linda Basin and Montebello Forebay Area. A substantial amount of sewage is exported to the pressure area and to the ocean.

In this basin, long-time mean annual net supply under present conditions is less than present annual demand, so an overdraft exists. Evaluation of items required* to estimate its amount follows.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Inflow

Estimated annual surface inflow averages 2,650 acre-feet, 2,760 acre-feet and 2,680 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 83. The estimate of inflow from 18,760 acres of directly tributary hills is based on the assumption that 10 percent of precipitation thereon runs off.†

Subsurface inflow, other than that indicated by note in Table 83, is negligible.

TABLE 83. SURFACE INFLOW TO LA HABRA BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	29-year period	21-year period	11-year period
From directly tributary hills			
Estimated [a]	2,590	2,700	2,620
From other basins			
Montebello Forebay Area	60	60	60
Total	2,650	2,760	2,680

[a] Includes a relatively small amount of underflow.

Import

In Table 84 estimated imports of water for each year since 1927-28 are presented. There is no import of sewage. Gravity and pumped water is imported from Central San Gabriel Valley Area and Montebello Forebay Area. During the 11-year period, an annual average of 18,400 acre-feet was imported. Estimated average annual import of water under present conditions is 18,830 acre-feet, equal to the average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 84. IMPORT TO LA HABRA BASIN

Year	Acre-feet	Year	Acre-feet	Year	Acre-feet
1927-28	15,830	1933-34	19,540	1939-40	17,720
1928-29	18,270	1934-35	14,960	1940-41	17,230
1929-30	18,890	1935-36	20,340	1941-42	17,960
1930-31	19,490	1936-37	17,860	1942-43	19,470
1931-32	19,180	1937-38	18,190	1943-44	19,360
1932-33	19,880	1938-39	19,300	1944-45	18,520

Consumptive Use

In Table 85 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. The cities of Whittier, La Habra and Brea overlie the basin. Avocado and citrus occupy

† If runoff from hills is assumed to follow the same regimen as flow in San Gabriel River, inflow from that source is 2,150 and 2,020 acre-feet in the 21- and 11-year periods, respectively.

by far the greater part of irrigated lands, both in the valley and on tributary hills. Unirrigated area is covered by light brush, weeds, and grass.

TABLE 85. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN LA HABRA BASIN

Type of culture	*Unit consumptive use, feet*	*1932 Acres*	*1932 Acre-feet*	*1942 Acres*	*1942 Acre-feet*
Valley and folded area					
Garden and field	1.2	914	1,097	830	996
Avocado and citrus	1.9	12,954	24,613	13,270	25,213
Deciduous	1.7	2,701	4,592	1,735	2,950
Alfalfa	2.5	211	528	211	528
Irrigated grass	2.5	212	530	212	530
Domestic and industrial	1.4	3,005	4,207	3,240	4,536
Unirrigated	----	5,651	----	6,150	----
29-year period	1.1	----	----	----	6,765
21-year period	1.124	----	----	----	6,913
11-year period	1.108	----	6,261	----	----
Subtotal	----	25,648	----	25,648	----
29-year period	----	----	----	----	41,518
21-year period	----	----	----	----	41,666
11-year period	----	----	41,828	----	----
Hill area					
Garden and field	0.0 [a]	10	0	10	0
Avocado and citrus	0.7 [a]	1,089	762	1,284	899
Irrigated grass	1.3 [a]	47	61	47	61
Domestic and industrial	0 2 [a]	97	19	132	26
Subtotal	----	1,243	842	1,473	986
Grand total	----	26,891	----	27,121	----
29-year period	----	----	----	----	42,504
21-year period	----	----	----	----	42,652
11-year period	----	----	42,670	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 86 estimated exports of water and sewage for each year since 1927-28 are presented. Water is exported to Central Coastal Plain Pressure Area, Montebello Forebay Area and Yorba Linda Basin. Sewage from the City of Whittier is exported to Central Coastal Plain pressure area, and that from the City of La Habra goes to the ocean. During the 11-year period an annual average of 1,520 acre-feet of water and 1,420 acre-feet of sewage was exported, a total of 2,940 acre-feet.

Estimated average annual export of water under present conditions is 1,100 acre-feet, equal to the average for the four-year period, 1941-42 to 1944-45, inclusive. Present annual export of sewage is estimated to be 2,340 acre-feet, the same as in 1944-45. Total estimated average annual export under present conditions is then 3,440 acre-feet.

TABLE 86. EXPORT FROM LA HABRA BASIN

(Acre-feet)

Year	Water	Sewage	Year	Water	Sewage
1927-28	1,180	1,300	1936-37	1,430	1,540
1928-29	1,230	1,340	1937-38	1,270	1,560
1929-30	1,250	1,380	1938-39	1,300	1,530
1930-31	2,070	1,380	1939-40	1,110	1,590
1931-32	1,790	1,380	1940-41	1,100	1,770
1932-33	1,750	1,380	1941-42	1,010	1,780
1933-34	1,640	1,420	1942-43	1,110	1,860
1934-35	1,350	1,480	1943-44	1,180	1,910
1935-36	1,720	1,480	1944-45	1,090	2,340

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary hills, part of that from Montebello Forebay Area, and runoff originating in precipitation on the overlying valley. It is estimated to average 2,520 acre-feet, 2,860 acre-feet and 2,580 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 87.

Inflow from the south face of Puente Hills, directly tributary to this basin, flows in several streams three to five miles across the basin, partly along paved streets in and adjacent to the cities of Whittier, La Habra and Brea, and partly in unpaved channels. Small inflow from Montebello Forebay Area enters La Habra Basin about three and one-half miles from its point of outflow.

Runoff in Brea Creek has been measured at Stations 1171 and 1172 since 1930-31, with exception of four months in 1939-40. That in East Fullerton Creek has been measured at stations 15611 and 1192 since 1930-41. Runoff for years prior to 1930-31, and for missing years since, is estimated from precipitation indices for the Coastal Plain Group, using rainfall-runoff relationships established during years of record. Runoff at gaging stations on Brea Creek is assumed to represent outflow from the basin. That proportion of runoff at gaging stations on East Fullerton Creek which originates within La Habra Basin is estimated to equal the proportion of the precipitation on the watershed which falls within the basin. Additional outflow is assumed to include 90 percent of the inflow from about 450 acres of hills at the extreme west end of the basin, and 50 percent of that from remaining hills not tributary to Brea Creek, together with 5 percent of precipitation on overlying valley land.

TABLE 87. SURFACE OUTFLOW FROM LA HABRA BASIN

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	29-year period	21-year period	11-year period
Measured during part of period	960	1,240	1,000
Estimated, originating in			
Directly tributary hills	460	480	470
Precipitation on valley and folded land	1,100	1,140	1,110
Total	2,520	2,860	2,580

Overdraft

If the 21-year period were assumed to be the cycle of long-time mean supply the estimated overdraft would be 20 acre-feet, as derived in Table 88. If the 29-year period were assumed to be the cycle, annual overdraft would be 1,040 acre-feet. The difference is due primarily to difference in estimated precipitation during the two cycles. Fifty-three year mean precipitation is greater than that in the 29-year period, and less than the 21-year average. Therefore, annual overdraft is estimated to be the average of the two values, or 530 acre-feet.

TABLE 88. ESTIMATED ANNUAL OVERDRAFT IN LA HABRA BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period	----	----	----	750
Items tending to increase the drop				
Consumptive use	42,650	42,670	—20	
Export	3,440	2,940	500	
Surface outflow	2,860	2,580	280	
Subtotal to be added				760
Items tending to decrease the drop				
Precipitation	32,960	31,980	980	
Surface inflow	2,760	2,680	80	
Import	18,830	18,400	430	
Subtotal to be subtracted				1,490
OVERDRAFT				20

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period must, in accordance with principles set forth in Chapter V, have averaged 5,620 acre-feet annually, as derived in Table 89.

TABLE 89. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM LA HABRA BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	31,980	
Surface inflow	2,680	
Import	18,400	
Water coming from storage in basin	750	
Subtotal		53,810
Water leaving basin on surface		
Surface outflow	2,580	
Exported water	1,520	
Exported sewage	1,420	
Consumptive use	42,670	
Subtotal		48,190
SUBSURFACE OUTFLOW—to Montebello Forebay Area		5,620

LOWER LOS ANGELES AND SAN GABRIEL RIVERS AREA

Hollywood Basin (32)
Los Angeles Forebay Area (33a)
Montebello Forebay Area (33b)
Central Coastal Plain Pressure Area (33e)
Los Angeles Narrows Basin (36)

There is no physical barrier to movement of ground water from Los Angeles Narrows Basin into Los Angeles Forebay Area, nor to movement from Los Angeles and Montebello Forebay areas into the Pressure Area, so the four are treated together. Hollywood Basin is served largely with imported water, and so great a part of this import is again exported for use in other portions of the City of Los Angeles that a separate estimate of excess supply in that basin is not only extremely difficult, but also serves no very useful purpose. For this reason Hollywood Basin is included as a component of Lower Los Angeles and San Gabriel Rivers area.

Lower Los Angeles and San Gabriel Rivers area is located in the north central portion of the coastal plain, and covers about 288 square miles. It is bounded on the north by Santa Monica Mountains and San Fernando Basin, on the northeast by San Rafael Hills and Pasadena subarea, on the east by Merced Hills, Main San Gabriel Basin and La Habra Basin, on the southeast by East Coastal Plain Pressure Area, and on the south and west by Inglewood Fault Zone.

Los Angeles Narrows Basin, covering about 13 square miles, consists largely of irregular narrow valleys between hills, with slopes varying greatly both in direction and steepness. Elevations range from 280 feet above sea level at the southerly boundary near Los Angeles River, to 700 feet along Arroyo Seco in the City of Pasadena. The channel of Los Angeles River is incised some 25 feet below the level of adjacent valley lands.

Hollywood Basin, with an area of about 15 square miles, is more regular. In the easterly three-quarters the slope to the south varies from about 60 to 700 feet per mile. In the westerly portion it is to the southeast, and averages about 150 feet per mile. Topography of the south central portion of the basin is smooth, with relatively flat slope to the south. Elevations vary from 155 feet above sea level east of Beverly Hills, to 600 feet above north of Hollywood.

Topography of Los Angeles Forebay area, covering about 47 square miles, is somewhat irregular and rolling in the northerly and easterly portions, but is more uniform in the central and southerly parts. Slopes are generally to the south and southwest, and range from 20 to more than 200 feet per mile. Elevation in the vicinity of the City of South Gate is 120 feet above sea level, while at the northeasterly extremity of the basin it is 500 feet. In the lower portion of the Forebay area, the Los Angeles River bed is slightly below adjacent land surface.

Both Rio Hondo and San Gabriel River traverse Montebello Forebay area. Topography is only slightly irregular throughout the central and southerly parts of the basin, but is decidedly irregular and rough in the folded area occupying the north central part. Slope is generally to the south and southwest, and varies from 15 to 225 or more feet per mile for valley lands. In the folded area slopes are extremely variable both in direction and magnitude. Elevations range from 105 feet to 325 feet above sea level in the valley, and to 630 feet above in the folded area.

Central Coastal Plain Pressure area extends in a general northwesterly-southeasterly direction, and covers 172 square miles. Topography is irregular, with slopes varying both in magnitude and direction. Elevation near the City of Long Beach is sea level, while at the easterly extremity of the pressure area an elevation of 300 feet above sea level is reached.

In Hollywood Basin soils range from heavy Montezuma clay adobe, through Chino and Ramona clays and loams, to light Hanford loams and sandy loams near the base of Santa Monica Mountains. In the remainder of the nonpressure portion of the area soils are principally lighter members of the Hanford and Ramona series, with the former predominating. Approximately two-thirds of the pressure area is covered by soils of the Hanford and Tujunga series, and the remainder by those of the less pervious Chino Series. These soils finger into one another throughout the pressure area, with Chino soils being somewhat more extensive in the lower portion.

Municipal development occupies virtually all of Hollywood Basin and Los Angeles Forebay area, and a very large part of the Los Angeles Narrows Basin, and of the pressure area west of Los Angeles River. In Montebello Forebay area, and in the pressure area east of Los Angeles River there is considerable municipal development, but it does not dominate the area. In Montebello Forebay area roughly two-thirds of agricultural land is devoted to citrus, while in the pressure area garden and field crops and alfalfa predominate. Most unirrigated land is covered by grass and weeds.

The local water supply, utilized to some extent by gravity diversions but more through pumping from ground water, originates in precipitation on valley lands, inflow from 8,180 acres of mountains and 25,160 acres of hills directly tributary to the nonpressure portion of the area, surface and subsurface inflow from San Fernando Valley area, Main San Gabriel and La Habra Basins, and surface inflow from

Western Unit of Raymond Basin Area. Water is imported in large amount, both for municipal use and for irrigation.

A relatively large part of the surface inflow to and precipitation on the nonpressure portion of the area flows out onto the pressure area, from whence it wastes to the ocean, mainly in Los Angeles and San Gabriel Rivers and Ballona Creek. Some water flows out underground across Inglewood Fault, which forms the lower southwesterly boundary of the pressure area. While there is no continuous barrier between East and Central Coastal Plain pressure areas, significant movement of ground water in either direction would require pronounced changes in the present pattern of pumping. Water and sewage are exported in large amounts.

The pressure area is characterized by virtually continuous beds of impervious clays, which lie between the ground surface and the main aquifers from which ground water is pumped for use. Because of this virtually all percolation from stream flow, precipitation and irrigation water in this area remains perched near the surface. The usable supply, pumped from deeper strata, virtually all originates in underflow from Los Angeles and Montebello Forebay areas and La Habra Basin. While recent studies indicate that small storage changes occur in the confined strata, by far the greater part of the regulation of supply to the pressure area and to the area as a whole is through storage changes in the nonpressure basins and forebay areas.

For the area as a whole, present demand is greater than average supply under present conditions, so an overdraft of considerable magnitude exists. In estimating the amount of this overdraft, significant items are change in storage, precipitation on, and surface inflow and import to the nonpressure portion of the area; surface outflow, consumptive use and export leaving the nonpressure portion of the area; and extractions from the pressure area. Evaluation of each of these items* follows.

Inflow to Nonpressure Portion of Area

Estimated annual surface inflow averages 168,910 acre-feet, 141,130 acre-feet and 123,360 acre-feet in the 29-, 21- and 11-year periods, respectively, as derived in Table 90.

About 21 percent of 8,180 acres of mountains, and 51 percent of 25,160 acres of hills, directly tributary to the nonpressure portion of the area are classified as having domestic or industrial culture. The acreage so developed is increasing (See Table 92). It is estimated† that 25 percent of the precipitation on these developed portions of mountain and hill area, 10 percent of that on remaining mountain area, and 9 percent of that on remaining hill area runs off. Surface inflow to Los Angeles Narrows Basin includes all surface outflow from San Fernando Valley Area, and that in Arroyo Seco from Western Unit of Raymond Basin Area. That to Montebello Forebay area includes all surface outflow from Main San Gabriel Basin, and a very small part of that from La Habra Basin.

Subsurface inflow to Los Angeles Narrows Basin includes all subsurface outflow from San Fernando Valley Area, estimated to be 7,110 acre-feet annually. That to Montebello Forebay Area, in addition to

* Values of change in storage and precipitation are presented in Tables 5 and 7.

† Eleven-year average runoff values at Stations 390, 1281, 1459 and 1525, are used as basis for estimates of runoff factors.

23,280 acre-feet from Main San Gabriel Basin, is assumed to include all subsurface outflow from La Habra Basin, estimated to be 5,620 acre-feet annually. Total annual subsurface inflow to Montebello Forebay Area is then 28,900 acre-feet, while to Lower Los Angeles and San Gabriel Rivers Area as a whole, it is 36,010 acre-feet.

TABLE 90. SURFACE INFLOW TO NONPRESSURE PORTION OF LOWER LOS ANGELES AND SAN GABRIEL RIVERS AREA

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Estimated [a]	1,580	1,650	1,590
From directly tributary hills			
Estimated [a]	6,090	6,330	6,020
From other basins			
San Fernando Valley Area	24,450	22,040	20,360
Raymond Basin Area	6,180	4,820	2,620
Main San Gabriel	130,530	106,200	92,680
La Habra	80	90	90
Total	168,910	141,130	123,360

[a] Includes a relatively small amount of underflow. Also includes precipitation on distributing reservoirs.

Import to Nonpressure Portion of Area

In Table 91 estimated imports to the nonpressure portion of the area for each year since 1927-28 are presented. There is no import of sewage. Water is imported from San Fernando Valley Area, Main San Gabriel and La Habra Basins, West Coastal Plain, Western Unit of Raymond Basin Area, Central Coastal Plain Pressure Area and from Colorado River. During the 11-year period, an annual average of 140,310 acre-feet of water was imported.

Average annual import from Main San Gabriel and La Habra Basins under present conditions is estimated to equal the historic average for the four-year period, 1941-42 to 1944-45, inclusive. For that from other sources, the 1944-45 value is assumed to represent the average annual under present conditions. Estimated total average annual import under present conditions is 214,930 acre-feet.

TABLE 91. IMPORT TO NONPRESSURE PORTION OF LOWER LOS ANGELES AND SAN GABRIEL RIVERS AREA

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	123,180	1933-34	132,520	1939-40	166,130
1928-29	131,020	1934-35	128,790	1940-41	164,580
1929-30	136,230	1935-36	149,980	1941-42	169,050
1930-31	143,720	1936-37	155,640	1942-43	185,560
1931-32	140,710	1937-38	160,450	1943-44	203,140
1932-33	141,120	1938-39	168,070	1944-45	215,260

Consumptive Use in Nonpressure Portion of Area

In Table 92 estimated values of average annual consumptive use in the nonpressure portion of Lower Los Angeles and San Gabriel Rivers Area, based on culture surveys conducted by the Division of Water Resources in 1932 and 1942, are presented. Unit consumptive use is discussed in Chapter V.

In Hollywood and Los Angeles Narrows Basins and Los Angeles Forebay Area expanding municipal development occupies 94 percent of valley and folded lands, and 49 percent of tributary mountain and hill area. Domestic and industrial culture in Montebello Forebay Area occupies about 26 percent of valley lands, while 46 percent is devoted to irrigated agriculture of which nearly two-thirds is in citrus. There are small areas of water-loving natural vegetation along river channels in and below Whittier Narrows. Of the relatively small area of unused lands in the area as a whole, the greater part is lying fallow and is covered by grass and weeds.

TABLE 92. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN NONPRESSURE PORTION OF LOWER LOS ANGELES AND SAN GABRIEL RIVERS AREA

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley and folded area					
Garden and field	1.1	3,308	3,639	3,408	3,749
Avocado and citrus	1.9	6,902	13,114	7,413	14,085
Deciduous	1.7	2,441	4,150	837	1,423
Alfalfa	2.5	810	2,025	680	1,700
Irrigated grass	2.5	940	2,350	995	2,487
Natural water-loving vegetation	4.0	193	772	193	772
Domestic and industrial[a]	1.4	5,333	7,466	7,046	9,864
Domestic and industrial[b]	1.0	44,375	44,375	44,914	44,914
Unirrigated	----	10,104	----	8,920	----
29-year period	0.9	----	----	----	8,020
21-year period	0.919	----	----	----	8,197
11-year period	0.906	----	9,154	----	----
Subtotal	----	74,406	----	74,406	----
29-year period	----	----	----	----	87,022
21-year period	----	----	----	----	87,191
11-year period	----	----	87,045	----	----
Hill and mountain area					
Garden and field	0.2[c]	16	3	16	3
Avocado and citrus	1.0[c]	71	71	71	71
Deciduous	0.8[c]	10	8	10	8
Evaporation from distributing reservoirs	3.2[d]	179	573	179	573
Irrigated grass	1.5[c]	811	1,216	866	1,299
Domestic and industrial[a]	0.5[c]	43	22	67	34
Domestic and industrial[b]	0.1[c]	13,829	1,383	14,409	1,441
Subtotal	----	14,959	3,276	15,618	3,429
Grand total	----	89,365	----	90,024	----
29-year period	----	----	----	----	90,451
21-year period	----	----	----	----	90,620
11-year period	----	----	90,321	----	----

[a] Montebello Forebay Area.
[b] Hollywood and Los Angeles Narrows Basins and Los Angeles Forebay Area.
[c] Difference between irrigated culture and natural vegetation.
[d] Difference between evaporation from reservoirs and consumptive use of natural vegetation.

Export From Nonpressure Portion of Area

In Table 93 estimated exports from the nonpressure portion of Lower Los Angeles and San Gabriel Rivers Area for each year since 1927-28 are presented. Water is exported to Main San Gabriel and La Habra Basins, West Coastal Plain, San Fernando Valley Area and Central Coastal Plain Pressure Area, while sewage goes to the ocean, to Main San Gabriel Basin, and to Central Coastal Plain Pressure Area. Export for use includes both gravity and pumped water. During the 11-year period, an annual average of 43,730 acre-feet of water, and 84,850 acre-feet of sewage was exported, a total of 128,580 acre-feet.

Estimated average annual export of water under present conditions is 74,570 acre-feet, and of sewage 120,680 acre-feet, a total of 195,250 acre-feet. Average annual export of water to Main San Gabriel and La Habra Basins from Montebello Forebay Area under present conditions is estimated to equal the historic average for the four-year period, 1941-42 to 1944-45, inclusive. For the remainder of the export, the 1944-45 value is assumed to represent the average under present conditions.

TABLE 93. EXPORT FROM NONPRESSURE PORTION OF LOWER LOS ANGELES AND SAN GABRIEL RIVERS AREA

(Acre-feet)

Year	*Water*	*Sewage*	*Year*	*Water*	*Sewage*
1927-28	36,560	70,440	1936-37	52,230	95,920
1928-29	39,730	80,500	1937-38	53,720	98,720
1929-30	40,960	85,250	1938-39	56,030	97,270
1930-31	42,390	85,340	1939-40	55,300	99,700
1931-32	42,750	85,630	1940-41	55,170	109,470
1932-33	41,590	83,680	1941-42	58,870	104,600
1933-34	40,510	75,350	1942-43	65,900	108,900
1934-35	38,940	85,200	1943-44	70,520	125,650
1935-36	51,600	87,280	1944-45	74,950	120,680

Surface Outflow From Nonpressure Portion of Area

Surface outflow from Los Angeles Forebay Area, and Hollywood and Los Angeles Narrows Basins includes part of the inflow from directly tributary mountains and hills, runoff originating in precipitation on valley lands, and inflow from San Fernando Valley Area, and from Western Unit of Raymond Basin Area in Arroyo Seco. Virtually all inflow from directly tributary mountains and hills, and valley runoff, is picked up on paved streets or in storm drains and carried directly to main drainage channels. The channel of Los Angeles River is paved throughout nearly the entire reach within the nonpressure portion of the area. Estimated surface outflow from this portion of the area includes 95 percent of the inflow from tributary hills and mountains, all surface inflow from other basins, and percentages of precipitation on various portions of overlying valley ranging from 20 percent on 3,480 acres, through 25 percent on 14,600 acres, and 30 percent on 21,190 acres, to 50 percent on 8,440 acres.

Nearly all surface outflow from Montebello Forebay Area is in Rio Hondo which has been measured at Station 1535 since March, 1928, and in San Gabriel River which has been measured at Station 1008 since February 6, 1928. Based on these measurements, 11-year average annual outflow in the two rivers is estimated to be 34,790 acre-feet. In addition, unmeasured outflow is estimated to include 90 percent of inflow from 1,290 acres of hills, and 25 percent of precipitation on 4,960 acres and 5 percent of that on 9,800 acres of valley and folded land, or 2,280 acre-feet annually during the 11-year period. Total average annual surface outflow during this period is then 37,070 acre-feet. Of this total, it is estimated that 20,780 acre-feet originated in mountain runoff from San Gabriel Canyon, and from Fish and Rogers Creeks, and that 16,290 acre-feet came from other sources.

Water flows out of Montebello Forebay Area on the surface for two reasons, (1) because the rate of surface inflow is greater than the percolating capacity of channels and spreading grounds in the area, and (2) because the underground storage capacity has not been sufficiently developed to completely regulate the inflow.

In estimating the long-time mean annual outflow for the first reason, it is arbitrarily assumed that the virtually unregulated outflow of water originating in sources other than the mountains above the mouth of San Gabriel Canyon is proportional to precipitation on the tributary area. Under this assumption present outflow from these sources averages 16,650 acre-feet annually for both the 29- and 21-year periods. Long-time mean annual outflow of water originating in San Gabriel Canyon, including that in Fish and Rogers Creeks, depends upon the degree of regulation achieved in the several upstream flood control reservoirs, and the effect on percolation of this regulation and extensive spreading both above and below Whittier Narrows. Under a plan of reservoir and spreading ground operation which reconciles as well as may be the conflicting interests of water conservation, flood control and the avoidance of a too high water table in San Gabriel Valley, and which is in reasonable agreement with plans of Los Angeles County Flood Control District, estimated outflow originating in this source averages 9,150 acre-feet annually in the 29-year period, and 6,850 acre-feet in the 21-year period.

Complete regulation of the remaining supply to Montebello Forebay Area, in order that there be no outflow for the second reason stated above, requires that extractions during the dry period of the cycle draw the water table down sufficiently to provide capacity enough to store not only the excess originating above the mouth of San Gabriel Canyon during the period, but also the excess rising water, which constitutes a large part of the inflow at the Narrows. Under the adopted plan of operation, overall fluctuation of the water table at Wells C-294 and C-294a will be somewhat greater than the historic depicted on Plate 11, and the variations in amount of rising water correspondingly greater than those indicated on Plate 24. It is estimated that complete regulation under the plan requires an overall fluctuation in Montebello Forebay Area of about 150 feet over the 29-year period and 110 feet over the 21-year period. Estimated total surface outflow from Montebello Forebay Area with these fluctuations thus averages 25,800 and 23,500 acre-feet in the two periods. With water table fluctuation in the forebay area limited to 100 feet, estimated average annual surface outflow is increased to 43,180 acre-feet and 25,580 acre-feet in the 29- and 21-year periods, respectively.

The historic range of fluctuation is about 50 feet, and just how far below sea level the piezometric surface in the pressure area near the ocean must be drawn down in order to achieve a 100-foot fluctuation in the forebay area with present pattern of pumping, is not known. With extractions near the ocean sufficiently reduced, and those in and near the forebay area correspondingly increased it could be above sea level at all time.

TABLE 94. SURFACE OUTFLOW FROM NONPRESSURE PORTION OF LOWER LOS ANGELES AND SAN GABRIEL RIVERS AREA

Average annual for 29-year period, 1904-05 to 1932-33, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	29-year period	*21-year period*	*11-year period*
Los Angeles Forebay Area, and Hollywood and Los Angeles Narrows Basins			
Estimated, originating in			
Surface inflow from San Fernando Valley Area	24,450	22,040	20,360
Surface inflow from Western Unit of Raymond Basin Area	6,180	4,820	2,620
Inflow from directly tributary mountains and hills	6,600	6,870	6,540
Precipitation on valley and folded land	19,180	19,890	19,330
Subtotal	56,410	53,620	48,850
Montebello Forebay Area	43,180	25,580	37,070
Total	99,590	79,200	85,920

Extractions From Coastal Plain Pressure Area

It is estimated that present annual extractions from the pressure area are 34,430 acre-feet greater than the average during the 11-year period, as derived in Table 95. About 56 percent of the total production, including that of most of the larger producers whose 1944-45 extractions were significantly different from the average for the 11-year period, has been measured. To estimate increase in unmeasured extractions, acreages of each type of culture lying outside of areas served by measured extractions, as determined by surveys conducted by the Division of Water Resources in 1932 and 1942, are used, together with estimated average values of duty for each culture type. By far the greater part of the change since 1942 has been in the domestic and industrial type, and 25 percent of the increase in estimated service to that type between 1932 and 1942 is added to allow for this change. Pumped water has been substituted for 310 acre-feet imported annually during the 11-year period.

TABLE 95. ESTIMATED DIFFERENCE BETWEEN 11-YEAR AVERAGE AND PRESENT ANNUAL EXTRACTIONS FROM CENTRAL COASTAL PLAIN PRESSURE AREA

	11-year average acre-feet	*1944-45 acre-feet*	*Increase, acre-feet*
Measured extractions			
Municipalities	28,920	33,720	4,800
Water districts and companies	16,120	33,510	17,390
Increase in measured extractions			22,190

	Acres served			*Duty, feet*	
	1932	*1942*	*Increase*		
Unmeasured extractions					
Garden and field	17,520	15,740	—1,780	1.0	—1,780
Avocado and citrus	1,640	1,830	190	1.5	280
Deciduous	1,200	720	—480	1.0	—480
Alfalfa	3,420	4,390	970	2.0	1,940
Irrigated grass	550	910	360	2.0	720
Domestic and industrial	9,400	15,400	6,000	1.5	9,000
Increase in use since 1942					2,250
Decrease in import					310
Increase in unmeasured extractions					12,240
Total increase in extractions					34,430

Overdraft

Assuming that the 21-year period represents a cycle of long-time mean supply, that reservoirs and spreading grounds are operated according to the plan herein adopted, and that fluctuations of the water table in Monebello Forebay Area are limited to a range of 100 feet, estimated annual overdraft is 12,270 acre-feet, as derived in Table 96. If 29-year mean values are substituted, the derived value is 8,890 acre-feet.

When outfall sewers to the ocean are completed for County Sanitation Districts 15 and 16 in San Gabriel Valley, inflow to Montebello Forebay Area will be decreased, and overdraft in Lower Los Angeles and San Gabriel Rivers Area increased by the amount of the sewage outflow. On the other hand, increased demand within the service area of the City of Los Angeles will not add to the overdraft unless extractions from the ground water of the Coastal Plain by the city are increased in lieu of utilizing a portion of the Mono Basin-Owens Valley aqueduct water herein considered as excess in San Fernando Valley Area, or increasing import from Colorado River.

TABLE 96. ESTIMATED ANNUAL OVERDRAFT IN LOWER LOS ANGELES AND SAN GABRIEL RIVERS AREA UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period				12,900 [a]
Items tending to increase the drop				
Nonpressure portion of area				
Consumptive use	90,620	90,320	300	
Surface outflow	79,200	85,920	—6,720	
Export	195,250	128,580	66,670	
Pressure area				
Extractions	----	----	34,430	
Subtotal to be added				94,680
Items tending to decrease the drop				
Nonpressure portion of area				
Precipitation	98,500	95,580	2,920	
Surface inflow	141,130	123,360	17,770	
Import	214,930	140,310	74,620	
Subtotal to be subtracted				95,310
OVERDRAFT				12,270

[a] Includes 2,580 acre-feet in pressure area.

CLAREMONT HEIGHTS BASIN (17)

Claremont Heights Basin is located below the mouth of San Antonio Canyon, on either side of the Los Angeles-San Bernardino County boundary, in the northwest portion of Upper Santa Ana Valley, and covers about eight square miles. It is bounded on the southwest by Live Oak Basin, on the northwest and north by San Gabriel Mountains, on the southeast by Chino Basin, and on the south by Pomona Basin. Topography is typical of the upper portion of cones built up by larger streams, exhibiting no large irregularities but cut by innumerable channels. Slope averages 200 feet per mile in a direction generally a little west of south. Elevations in the valley range from 1,300 to 2,100 feet above sea level. Soils are mostly lighter and rockier members of the Hanford and Tujunga series, and are very receptive of moisture. Stream channels are poorly defined and percolation opportunity is large. Agricultural development covers about 36 percent of the area, the rest being still in its natural state, except for a small acreage of domestic culture.

The local water supply, utilized in part through diversion from surface streams, and in part through pumping from ground water, originates in precipitation on the valley, and inflow from 19,780 acres of mountains directly tributary to the basin. A very small amount of water is imported.

A relatively small part of the surface inflow and precipitation flows out into Chino Basin, together with considerable underflow into Chino, Live Oak and Pomona Basins, and water is exported in relatively large amount to Chino, Pomona and Cucamonga Basins.

In Claremont Heights Basin, long-time mean annual net supply under present conditions is slightly less than present annual demand if the 21-year period is assumed to represent the long-time mean cycle of supply and somewhat greater if the 32-year cycle is used, indicating an overdraft under one assumption and an excess under the other. Evaluation of items required* to estimate the amount of overdraft or excess follows.

Inflow

Estimated annual surface inflow averages 24,630 acre-feet, 23,260 acre-feet and 22,260 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 97.

Annual inflow from a portion of the directly tributary mountain area was measured in San Antonio Creek, at Stations 5628 and 5638 during the entire period.

The estimate of 32-year mean annual inflow from 8,990 acres of mountains directly tributary to the basin, and downstream from gaging stations at which above inflow was measured is based on the assumption that, if water is available, average consumptive use on the mountain area is 18 inches. Average inflow from the greater part of mountains during the 11-year base period is estimated to be 0.91 times the 32-year mean, this being the ratio between 11- and 32-year mean discharge of San Antonio Creek. For mountain areas in the westerly portion, however, the ratio is that for San Gabriel River, i.e. 0.81. Corresponding ratios for the 21-year period are 0.95 and 0.86.

Subsurface inflow, other than that indicated by note in Table 97, is negligible.

TABLE 97. SURFACE INFLOW TO CLAREMONT HEIGHTS BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38 inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Measured during entire period	17,410	16,510	15,820
Estimated [a]	7,220	6,750	6,440
Total	24,630	23,260	22,260

[a] Includes a relatively small amount of underflow.

Import

In Table 98 estimated values of imports of water for each year since 1927-28 are presented. There is no import of sewage. During the 11-year period an annual average of 100 acre-feet of water was imported from Pomona Basin.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Estimated average annual import under present conditions is 80 acre-feet, equal to the average for the seven-year period, 1938-39 to 1944-45, inclusive.

TABLE 98. IMPORT TO CLAREMONT HEIGHTS BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	0	1933-34	10	1939-40	280
1928-29	0	1934-35	30	1940-41	20
1929-30	0	1935-36	120	1941-42	0
1930-31	100	1936-37	140	1942-43	0
1931-32	340	1937-38	170	1943-44	0
1932-33	250	1938-39	260	1944-45	0

Consumptive Use

In Table 99 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. The area occupied by domestic development is small and there are no industries. A large part of the unused land is included in the wash of San Antonio Creek and adjoining spreading grounds. These are largely covered by brush.

TABLE 99. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN CLAREMONT HEIGHTS BASIN

Type of culture	*Unit consumptive use, feet*	*1932 Acres*	*1932 Acre-feet*	*1942 Acres*	*1942 Acre-feet*
Valley area					
Garden and field	1.3	15	20	5	6
Avocado and citrus	2.0	1,557	3,114	1,787	3,574
Irrigated grass	3.0	40	120	35	105
Domestic and industrial	1.5	142	213	142	213
Unirrigated	----	3,378	----	3,163	----
32-year period	1.7	----	----	----	5,377
21-year period	1.692	----	----	----	5,352
11-year period	1.669	----	5,638	----	----
Total	----	5,132	----	5,132	----
32-year period	----	----	----	----	9,275
21-year period	----	----	----	----	9,250
11-year period	----	----	9,105	----	----

Export

In Table 100 estimated values of exports of water for each year since 1927-28 are presented. There is no sewage outflow. Water from both gravity and pumped sources is exported to Chino, Live Oak, Pomona and Cucamonga Basins. During the 11-year period, an annual average of 14,200 acre-feet of water was exported.

The amount of gravity water exported depends to some extent upon the amount available. Average annual export of San Antonio Creek water to Cucamonga Basin under present conditions has been discussed in connection with import to that basin. Export of purely gravity water to Pomona Basin was measured throughout the 21-year period. Present average annual export of purely pumped water is assumed to equal its average for the four year period, 1941-42 to 1944-45, inclusive. Present export of combined pumped and gravity water to Chino Basin by a single company is estimated to equal the company's four-year average annual import to Chino Basin from both Claremont Heights and Cucamonga Basins, *minus* its long time average annual import under present conditions from Cucamonga Basin alone. Estimated total average annual export under present conditions is 17,940 acre-feet.

TABLE 100. EXPORT FROM CLAREMONT HEIGHTS BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	12,510	1933-34	8,920	1939-40	17,870
1928-29	11,290	1934-35	15,430	1940-41	20,570
1929-30	12,920	1935-36	15,920	1941-42	17,710
1930-31	10,560	1936-37	19,880	1942-43	19,650
1931-32	15,770	1937-38	20,780	1943-44	23,550
1932-33	12,180	1938-39	16,600	1944-45	22,560

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and runoff originating in precipitation on the overlying valley. It is estimated to average 2,110 acre-feet, 2,140 acre-feet, and 3,120 acre-feet annually during the 32-, 21- and 11-year periods, respectively, as derived in Table 101.

Inflow of mountain water is mostly in San Antonio Creek, which flows about four miles across the basin in unpaved channels. Large spreading grounds augment natural percolation from this stream, and it is only in time of high water that any flow leaves the basin.

A record of daily discharges of San Antonio Creek at Stations 5628 and 5638 since October 1, 1904, is available. Runoff from a considerable area of mountains draining into the creek below the station is estimated to be 76 percent of the discharge at the gaging station on days of high flow. Daily discharges at the canyon mouth are estimated on this basis for years prior to 1931-32. After that time a record is available at Station 4514, near that point. Of the flow at the canyon mouth, 30 second-feet is assumed to be diverted for use when available, and the remainder up to 330 second-feet, diverted to spreading at all times except during extreme flood periods. During the first 10 years of the 11-year period no discharge was sufficiently great to reach the lower boundary of the basin. In 1937-38 the spreading grounds were so damaged that, out of a total runoff of 42,300 acre-feet at Station 4514, only about 16,800 acre-feet percolated or was spread, and 25,500 acre-feet is estimated to have flowed out.

To estimate outflow in the creek during 32- and 21-year periods, estimated daily discharges below the spreading grounds and a percolation curve which results in complete percolation up to 23 second-feet, are used. In estimating outflow under present conditions, possible effects of proposed flood control works on San Antonio Wash are not considered. Any reduction in natural percolation due to lining channels can be offset by increased spreading.

It is assumed that all runoff from mountains above Thompson Creek Dam percolates in the reservoir, or is spread below the dam. It is estimated that 90 percent of inflow from about 500 acres of mountains tributary to Thompson Creek below the dam, 5 percent of precipitation on 340 acres of valley land in the westerly portion of the area, 2 percent of precipitation on about 4,370 acres of remaining valley land, and 90 percent of inflow from 1,020 acres of mountain area in the easterly portion of the basin which is not tributary to San Antonio Wash runs out.

TABLE 101. SURFACE OUTFLOW FROM CLAREMONT HEIGHTS BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Estimated, originating in			
San Antonio Creek	1,220	1,300	2,320
Directly tributary mountains	700	650	620
Precipitation on valley land	190	190	180
Total	2,110	2,140	3,120

Overdraft

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual overdraft is 1,420 acre-feet, as derived in Table 102. If 32-year mean values are substituted in the table an annual excess of 50 acre-feet is indicated.

TABLE 102. ESTIMATED ANNUAL OVERDRAFT IN CLAREMONT HEIGHTS BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual rise in storage during base period	----	----	----	270
Items tending to increase the rise				
Precipitation	9,390	9,150	240	
Surface inflow	23,260	22,260	1,000	
Import	80	100	—20	
Subtotal to be added				1,220
Items tending to decrease the rise				
Consumptive use	9,250	9,100	150	
Surface outflow	2,140	3,120	—980	
Export	17,940	14,200	3,740	
Subtotal to be subtracted				2,910
OVERDRAFT				1,420

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must, in accordance with principles set forth in Chapter V, have averaged 4,820 acre-feet annually, as derived in Table 103. Its distribution between the three basins is arbitrary, based upon requirements in those basins and behavior of wells therein.

TABLE 103. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM CLAREMONT HEIGHTS BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	9,150	
Surface inflow	22,260	
Import	100	
Water coming from storage in basin	—270	
Total		31,240
Water leaving basin on surface		
Surface outflow	3,120	
Export	14,200	
Consumptive use	9,100	
Total		26,420
SUBSURFACE OUTFLOW		4,820
To Live Oak Basin		3,320
To Pomona Basin		1,000
To Chino Basin		500

LIVE OAK BASIN (18)

Live Oak Basin is located in the extreme northwest corner of Upper Santa Ana Valley, and covers about 3.1 square miles. It is bounded on the northwest by San Dimas Basin, on the north by San Gabriel Mountains, on the northeast by Claremont Heights Basin, and on the south by Pomona Basin. Topography is irregular, particularly in its northern part where the alluvium extends steeply upward into the mountains. In the lower portions, west of Thompson Creek, slope varies from 60 to 175 feet per mile, and is to the west and southwest. East of that stream the slope averages about 125 feet per mile in a direction a little west of south. Here the topography is relatively smooth. Elevations in the valley range from 1,000 to 1,350 feet above sea level. The alluvium extends to elevation 1,600 in the mountains. Soils covering this basin are mostly lighter members of the Hanford series, with a considerable area of somewhat less pervious Ramona loam in and below the canyon mouth. Only about 2 percent of the area is covered by culture of a municipal type, about 82 percent is devoted to agriculture, and about 16 percent is in a more or less natural state.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on the valley, inflow from 2,000 acres of mountains directly tributary to the basin, and both subsurface and surface inflow from Claremont Heights Basin, the greater part of the last named as flood flow in Thompson Creek. Imported water provides a relatively large addition to the supply.

A considerable part of surface inflow and precipitation flows out into Pomona Basin, together with material underflow, and water is exported in relatively large amount to San Dimas and Pomona Basins.

In this basin, long-time mean annual net supply, under present conditions is a little greater than present annual demand, so a small excess exists. Evaluation of items required * to estimate its amount follows.

Inflow

Estimated annual surface inflow averages 430 acre-feet, 370 acre-feet, and 310 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 104.

Annual inflow from a portion of the directly tributary mountain area was measured in Live Oak Creek at Station 4457 for several years. Average values for all three periods are derived by comparison with San Dimas Creek.

The estimate of 32-year mean annual inflow from 460 acres of mountains directly tributary to the basin, and downstream from the gaging station at which above inflow was measured, is based on the assumption that average consumptive use on mountain area is 22 inches, runoff however never being less than 7 percent of the precipitation. The 11-year value is estimated to be 0.81 times the 32-year mean, this being the ratio between 11- and 32-year mean discharge of San Gabriel River. The corresponding ratio for the 21-year period is 0.86.

Surface outflow from a small area at the westerly edge of Claremont Heights Basin enters Live Oak Basin, as does a part of the underflow from that basin. The latter is estimated to average 3,320 acre-feet annually.

TABLE 104. SURFACE INFLOW TO LIVE OAK BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Measured during part of period	210	180	140
Estimated [a]	60	50	40
From other basins			
Claremont Heights	160	140	130
Total[a]	430	370	310

[a] Includes a relatively small amount of underflow.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Import

In Table 105 estimated values of imports of water for each year since 1927-28 are presented. There is no import of sewage. During the 11-year period, an annual average of 1,810 acre-feet of water was imported from San Dimas, Claremont Heights and Pomona Basins.

Estimated average annual import under present conditions is 2,030 acre-feet, equal to the average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 105. IMPORT TO LIVE OAK BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	1,320	1933-34	2,080	1939-40	1,580
1928-29	1,630	1934-35	1,660	1940-41	1,510
1929-30	1,570	1935-36	2,110	1941-42	1,900
1930-31	1,800	1936-37	1,990	1942-43	2,050
1931-32	1,910	1937-38	1,730	1943-44	1,960
1932-33	2,080	1938-39	1,610	1944-45	2,210

Consumptive Use

In Table 106 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. While soils covering a considerable part of Live Oak Basin are rocky and difficult to work, about 82 percent of the area is profitably devoted to production of citrus fruits. Industrial development is negligible and domestic use relatively small. Brush covers most of the unused land.

TABLE 106. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN LIVE OAK BASIN

Type of culture	*Unit consumptive use, feet*	*1932 Acres*	*1932 Acre-feet*	*1942 Acres*	*1942 Acre-feet*
Valley area					
Avocado and citrus	2.0	1,624	3,248	1,624	3,248
Domestic and industrial	1.5	32	48	37	56
Unirrigated	----	317	----	312	----
32- and 21-year periods	1.5	----	----	----	468
11-year period	1.484	----	470	----	----
Subtotal	----	1,973	----	1,973	----
32- and 21-year periods	----	----	----	----	3,772
11-year period	----	----	3,766	----	----
Mountain area					
Avocado and citrus	0.4[a]	34	14	34	14
Grand total	----	2,007	----	2,007	----
32- and 21-year periods	----	----	----	----	3,786
11-year period	----	----	3,780	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 107 estimated exports of water to San Dimas and Pomona Basins for each year since 1927-28 are presented. There is no sewage outflow. During the 11-year period an annual average of 1,170 acre-feet of water was exported. Estimated average annual export under present conditions is 1,280 acre-feet, equal to the average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 107. EXPORT FROM LIVE OAK BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	1,100	1933-34	1,200	1939-40	960
1928-29	1,400	1934-35	950	1940-41	950
1929-30	1,260	1935-36	1,100	1941-42	1,230
1930-31	1,190	1936-37	1,140	1942-43	1,270
1931-32	1,320	1937-38	1,010	1943-44	1,160
1932-33	1,220	1938-39	980	1944-45	1,440

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains, part of that from Claremont Heights Basin and runoff originating in precipitation on the overlying valley. It is estimated to average 360 acre-feet, 330 acre-feet and 300 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 108.

Mountain inflow is mostly in Live Oak Creek, which flows 1.9 miles across the basin. Records of daily discharge from Live Oak Reservoir and at Station 4457 during the 11-year period are available. Eleven-year average annual outflow in the creek is estimated by using these records and a percolation curve which results in complete percolation up to four second-feet. Thirty-two- and 21-year average outflows are assumed proportional to estimated average annual runoff at the gaging station.

Estimated outflow from other sources includes 50 percent of inflow from directly tributary mountains, 50 percent of inflow from other basins, and 5 percent of precipitation on the overlying valley area.

TABLE 108. SURFACE OUTFLOW FROM LIVE OAK BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Estimated, originating in			
Live Oak Creek	90	80	60[a]
Directly tributary mountains	30	20	20
Inflow from other basins	80	70	60
Precipitation on valley land	160	160	160
Total	360	330	300

[a] Based on daily discharges at gaging station and percolation curve.

Excess

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual excess is 210 acre-feet, as derived in Table 109. If 32-year mean values are substituted in the table the derived annual excess is 240 acre-feet.

TABLE 109. ESTIMATED ANNUAL EXCESS IN LIVE OAK BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual increase in storage during base period	----	----	----	10
Items tending to increase the rise				
Precipitation	3,280	3,210	70	
Surface inflow	370	310	60	
Import	2,030	1,810	220	
Subtotal to be added				350
Items tending to decrease the rise				
Consumptive use	3,790	3,780	10	
Surface outflow	330	300	30	
Export	1,280	1,170	110	
Subtotal to be subtracted				150
EXCESS				210

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period must, in accordance with principles set forth in Chapter V, have averaged 3,390 acre-feet annually, as derived in Table 110.

TABLE 110. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM LIVE OAK BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	3,210	
Surface inflow	310	
Import	1,810	
Underflow	3,320	
Water coming from storage in basin	—10	
Subtotal		8,640
Water leaving basin on surface		
Surface outflow	300	
Export	1,170	
Consumptive use	3,780	
Subtotal		5,250
SUBSURFACE OUTFLOW—to Pomona Basin		3,390

POMONA BASIN (19)

Pomona Basin is located in the northwesterly portion of Upper Santa Ana Valley, and covers about 8.5 square miles. It is bounded on the southwest by San Jose Hills, on the north by Live Oak and Claremont Heights Basins, and on the southeast by Chino Basin. Topography is for the most part regular, with slope averaging about 125 feet per mile in a direction generally a little west of south. Elevations above sea level range from 900 to 1,350 feet. Soils are mostly lighter members of the Hanford series, and are quite receptive of moisture. About 21 percent of the area is covered by culture of a municipal type, about 59 percent is devoted to agriculture, and about 20 percent is in a more or less natural state.

The local water supply, utilized through pumping from ground water, originates in precipitation on the valley, inflow from 380 acres of hills directly tributary to the basin, and surface and subsurface inflow from Live Oak and Claremont Heights Basins. Imported water provides a relatively large addition to the supply.

A considerable part of the surface inflow and precipitation flows out into Spadra and Chino Basins, together with some underflow into the latter, and water is exported in relatively large amount to San Dimas, Chino, Live Oak and Spadra Basins, with a little to Main San Gabriel and Claremont Heights Basins. Sewage is exported for use in Puente Basin.

In this basin, long-time mean annual net supply under present conditions is less than present annual demand, so an overdraft exists. Evaluation of items required* to estimate its amount follows.

Inflow

Estimated annual surface inflow averages 420 acre-feet, 390 acre-feet and 360 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 111.

The estimate of 32-year annual inflow from 380 acres of directly tributary hills is based on the assumption that, if water is available, average consumptive use on the hills is 17 inches, inflow however being never less than 9½ percent of precipitation thereon. The 11-year value is estimated to be 0.98 times the 32-year mean, this being the ratio between 11- and 32-year mean, precipitation on the area represented by the San Gabriel Group. The corresponding ratio for the 21-year period is 1.00.†

All subsurface outflow from Live Oak Basin, and a part of that from Claremont Heights Basin is assumed to enter Pomona Basin. Estimated average subsurface inflow from these sources amounts to 3,390 and 1,000 acre-feet, respectively, a total of 4,390 acre-feet annually.

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* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

† If runoff from hills is assumed to follow the same regimen as flow in San Gabriel River, average annual inflow during the 21-year period is 50 acre-feet, the same as for the 11-year period.

TABLE 111. SURFACE INFLOW TO POMONA BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
From directly tributary hills			
Estimated [a]	60	60	60
From other basins			
Live Oak	360	330	300
Total	420	390	360

[a] Includes a relatively small amount of underflow.

Import

In Table 112 estimated values of imports of water for each year since 1927-28 are presented. There is no import of sewage. During the 11-year period, an average of 3,930 acre-feet was imported from both gravity and pumped sources in San Dimas, Claremont Heights and Live Oak Basins.

The amount of water imported depends to some extent upon the amount of gravity water available. Gravity diversions cannot be expected to maintain the high values of recent years of above-normal rainfall and stream-flow over a long-time cycle of supply, and it therefore assumed that average annual import of gravity water from Claremont Heights Basin under present conditions is equal to its average for the 21-year period. Assuming further that present average annual import from other sources is the average for the four year period, 1941-42 to 1944-45, inclusive, present import totals 4,600 acre-feet annually.

TABLE 112. IMPORT TO POMONA BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	3,820	1933-34	2,890	1939-40	4,490
1928-29	3,650	1934-35	3,220	1940-41	4,610
1929-30	4,050	1935-36	4,620	1941-42	5,030
1930-31	3,380	1936-37	4,480	1942-43	4,150
1931-32	3,520	1937-38	5,640	1943-44	4,920
1932-33	3,920	1938-39	4,920	1944-45	5,200

Consumptive Use

In Table 113 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. Municipal development includes the City of Claremont, and portions of the cities of La Verne and Pomona. Natural vegetation growing on unused land is mostly light brush, weeds and grass.

TABLE 113. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN POMONA BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley Area					
Garden and field	1.3	215	280	45	58
Avacado and citrus	2.0	2,828	5,656	2,871	5,742
Deciduous	1.8	429	772	324	583
Irrigated grass	3.0	3	9	0	0
Domestic and industrial	1.5	1,022	1,533	1,155	1,732
Unirrigated	----	961	----	1,063	----
32- and 21-year periods	1.4	----	----	----	1,488
11-year period	1.385	----	1,331	----	----
Subtotal	----	5,458	----	5,458	----
32- and 21-year periods	----	----	----	----	9,603
11-year period	----	----	9,581	----	----
Hill area					
Garden and field	0 [a]	4	0	4	0
Avocado and citrus	0.6 [a]	29	17	29	17
Deciduous	0.4 [a]	10	4	10	4
Irrigated grass	1.6 [a]	15	24	15	24
Domestic and industrial	0.1 [a]	0	0	15	2
Subtotal		58	45	73	47
Grand total	----	5,516	----	5,531	----
32- and 21-year periods	----	----	----	----	9,650
11-year period	----	----	9,626	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 14 estimated exports of water and sewage for each year since 1927-28 are presented. Water is exported to Main San Gabriel, San Dimas, Chino, Claremont Heights, Live Oak and Spadra Basins, while sewage goes to Puente Basin. During the 11-year period an annual average of 8,260 acre-feet of water, and 370 acre-feet of sewage was exported, a total of 8,630 acre-feet.

Average annual exports of water under present conditions, by all but one exporter whose import to San Dimas Basin ranges up to a fixed maximum depending upon the amount of gravity water available in that basin, are assumed the same as the average for the four-year period, 1941-42 to 1944-45, inclusive. The total is 8,120 acre-feet. Sewage outflow, assumed equal to the value for 1944-45 amounts to 740 acre-feet per year. The total for both water and sewage is 8,860 acre-feet per year.

TABLE 114. EXPORT FROM POMONA BASIN

(Acre-feet)

Year	Water	Sewage	Year	Water	Sewage
1927-28	10,180	290	1936-37	6,010	470
1928-29	9,950	320	1937-38	7,510	460
1929-30	9,370	320	1938-39	7,070	460
1930-31	9,690	350	1939-40	6,920	480
1931-32	8,700	360	1940-41	6,200	510
1932-33	8,270	330	1941-42	6,470	590
1933-34	7,520	350	1942-43	7,620	700
1934-35	5,690	410	1943-44	7,460	740
1935-36	7,990	410	1944-45	7,790	740

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary hills, part of that from Live Oak Basin and runoff originating in precipitation on the overlying valley. It is estimated to average 1,200 acre-feet, 1,180 acre-feet and 1,140 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 115.

Inflow to this basin directly from hills enters the channel of San Jose Creek not far from its point of outflow, and it is assumed that 50 percent of this inflow leaves the basin. Inflow from Live Oak Basin is in several channels, all of which are confined and most of which are paved throughout the greater part of their length in the basin. There is, however, some percolation opportunity in unpaved sections. A part of this inflow eventually reaches Spadra Basin, and a part goes to San Dimas Basin. It is assumed that 50 percent of that tributary to the former, and 100 percent of that tributary to the latter leaves Pomona Basin. Of precipitation on the valley, it is assumed that 10 percent of that tributary to Spadra and Chino Basins, and 15 percent of that tributary to San Dimas Basin flows out.

TABLE 115. SURFACE OUTFLOW FROM POMONA BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Estimated, originating in			
Directly tributary hills	30	30	30
Inflow from other basins	250	230	210
Precipitation on valley land	920	920	900
Total	1,200	1,180	1,140

Overdraft

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual overdraft is 2,170 acre-feet, as derived in Table 116. If 32-year mean values are substituted in the table, the derived annual overdraft is 2,160 acre-feet.

TABLE 116. ESTIMATED ANNUAL OVERDRAFT IN POMONA BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period	----	----	----	2,760
Items tending to increase the drop				
Consumptive use	9,650	9,630	20	
Export	8,860	8,630	230	
Surface outflow	1,180	1,140	40	
Subtotal to be added				290
Items tending to decrease the drop				
Precipitation	8,660	8,480	180	
Surface inflow	390	360	30	
Import	4,600	3,930	670	
Subtotal to be subtracted				880
OVERDRAFT				2,170

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must, in accordance with principles set forth in Chapter V, have averaged 520 acre-feet annually, as derived in Table 117.

TABLE 117. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM POMONA BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	8,480	
Surface inflow	360	
Import	3,930	
Subsurface inflow	4,390	
Water coming from storage in basin	2,760	
Subtotal		19,920
Water leaving basin on surface		
Surface outflow	1,140	
Exported water	8,260	
Exported sewage	370	
Consumptive use	9,630	
Subtotal		19,400
SUBSURFACE OUTFLOW—to Chino Basin		520

CUCAMONGA BASIN (20)

Cucamonga Basin is located in the northwesterly portion of Upper Santa Ana Valley, and covers about 13 square miles. It is bounded on the southwest, south and east by Chino Basin, and on the north by San Gabriel Mountains. Topography is definitely irregular at its southern boundary. Elsewhere many minor irregularities, typical of the upper portion of cones generally, cover a considerable part of the area. Slope ranges between 200 and 250 feet per mile, in a direction a little east of south. Elevations range from 1,250 to about 2,300 feet above sea level. Soils covering this basin are mostly lighter members of the Hanford and Tujunga series, with a fairly large area of less pervious Placentia loam near the lower boundary. Municipal development occupies only about 2 percent of the area, about 46 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on the valley, and inflow from 9,370 acres of mountains directly tributary to the basin. Imported water provides a relatively large addition to the supply.

A considerable part of the surface inflow and precipitation flows out into Chino Basin, together with some underflow, and water is exported in relatively large amount to the same basin.

In this basin, long-time mean annual net supply under present conditions is greater than present annual demand, so an excess exists. Evaluation of items required * to estimate its amount follows.

Inflow

Estimated annual surface inflow averages 8,300 acre-feet, 7,870 acre-feet and 7,450 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 118.

Annual inflow from a portion of the directly tributary mountain area was measured in Cucamonga Creek at Station 4572 during a part of each period. The 32- and 21-year values are derived by comparison with San Antonio Creek.

The estimate of the 32-year mean annual inflow from 2,900 acres of mountains directly tributary to the basin is based on the assumption that average consumptive use on mountain area is 17 inches. The 11-year and 21-year values are estimated to be, respectively, 0.91 and 0.95 times the 32-year mean, these being the ratios between 11- and 21-year averages, and 32-year mean discharge of San Antonio Creek.

The only subsurface inflow is that indicated by note in Table 118.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

TABLE 118. SURFACE INFLOW TO CUCAMONGA BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Measured during part of period	6,130	5,810	5,470
Estimated [a]	2,170	2,060	1,980
Total	8,300	7,870	7,450

[a] Includes a relatively small amount of underflow.

Import

In Table 119 estimated values of imports of water for each year since 1927-28 are presented. There is no import of sewage. Gravity water is imported from Claremont Heights Basin and spread in Cucamonga Wash. Pumped water is imported from Chino Basin. During the 11-year period, an annual average of 3,840 acre-feet of water was imported.

The amount of gravity water imported depends to some extent upon the amount available. Total gravity diversions from San Antonio Canyon and the portion diverted to Cucamonga Basin have been measured since 1918 and since 1927-28 respectively. Average annual import of gravity water under present conditions is estimated to equal the mean diversion from San Antonio Creek during the 21-year period multiplied by the ratio between diversion to Cucamonga Basin and total diversion since 1927-28. Assuming that present import of water pumped in Chino Basin equals its average for the four-year period, 1941-42 to 1944-45, inclusive, estimated total present average annual import to Cucamonga Basin is 4,340 acre-feet.

TABLE 119. IMPORT TO CUCAMONGA BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	2,370	1933-34	1,930	1939-40	6,050
1928-29	2,190	1934-35	6,770	1940-41	7,580
1929-30	3,010	1935-36	3,490	1941-42	5,080
1930-31	2,790	1936-37	6,620	1942-43	5,160
1931-32	4,900	1937-38	5,920	1943-44	6,730
1932-33	2,290	1938-39	3,540	1944-45	6,110

Consumptive Use

In Table 120 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. Municipal development is small and industrial development negligible. Natural vegetation growing on unused land is largely brush, weeds and grass.

TABLE 120. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN CUCAMONGA BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley area					
Garden and field	1.3	211	274	176	229
Avocado and citrus	2.3	2,768	6,366	3,363	7,735
Deciduous	2.1	390	819	375	788
Alfalfa	3.0	5	15	5	15
Domestic and industrial	1.8	147	265	167	301
Unirrigated	----	5,007	----	4,442	----
32-year period	1.5	----	----	----	6,663
21-year period	1.492	----	----	----	6,627
11-year period	1.473	----	7,375	----	----
Subtotal	----	8,528	----	8,528	----
32-year period	----	----	----	----	15,731
21-year period	----	----	----	----	15,695
11-year period	----	----	15,114	----	----
Mountain area					
Avocado and citrus	0.8[a]	15	12	15	12
Grand total	----	8,543	----	8,543	----
32-year period	----	----	----	----	15,743
21-year period	----	----	----	----	15,707
11-year period	----	----	15,126	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 121 estimated exports of water for each year since 1927-28 are presented. There is no sewage outflow. During the 11-year period, an annual average of 10,060 acre-feet of water was exported to Chino Basin from wells and tunnels in the alluvium. Nearly half the total export is by an entity which also diverts by gravity from San Antonio Canyon. Less pumped water is required when more gravity water is available. Average annual export by this entity, under present conditions, is assumed to equal its average for the four-year period, 1941-42 to 1944-45, inclusive, multiplied by the ratio between the four-year and 21-year average annual diversions from San Antonio Canyon. The remainder of the export is independent of gravity diversions and is assumed equal to the four-year average. Estimated present average annual export totals 10,240 acre-feet.

TABLE 121. EXPORT FROM CUCAMONGA BASIN

Year	Acre-feet	Year	Acre-feet	Year	Acre-feet
1927-28	10,740	1933-34	12,370	1939-40	7,720
1928-29	12,370	1934-35	7,030	1940-41	5,550
1929-30	11,550	1935-36	10,780	1941-42	8,980
1930-31	12,000	1936-37	6,240	1942-43	8,640
1931-32	9,100	1937-38	6,980	1943-44	9,090
1932-33	11,480	1938-39	9,840	1944-45	9,260

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and runoff originating in precipitation on the overlying valley. It is estimated to average 1,390 acre-feet, 1,080 acre-feet and 1,200 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 122.

The greater part of the mountain inflow is concentrated in Cucamonga Creek, which flows southward four miles across the basin. In its upper reaches 12 rock and wire wall dams extend across the arroyo in which the stream flows. While intended primarily for retention of debris, these walls effect some spreading. Spreading grounds below these cross walls were destroyed in 1938. During the 1933-34 season a peak flow of approximately 300 second-feet was entirely absorbed within the area of 65 acres enclosed by the cross walls.

None of the channels of Cucamonga Creek, nor of the much smaller streams on either side are paved, but flow past the spreading ground area occurs on so few days that percolation in the channel below is not considered. Outflow since 1927-28, when Station 4572 was established, is estimated by subtracting 300 second-feet from daily discharges at that station. From the relationship thus established between inflow and outflow during years of record, 32- and 21-year mean annual outflows in Cucamonga Creek are estimated.

Estimated outflow from other sources includes 25 percent of the inflow from directly tributary mountains, and 2 percent of the precipitation on valley area within the basin.

TABLE 122. SURFACE OUTFLOW FROM CUCAMONGA BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Estimated, originating in			
Cucamonga Creek	530	240	400
Directly tributary mountains	540	520	490
Precipitation on valley land	320	320	310
Total	1,390	1,080	1,200

Excess

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual excess is 290 acre-feet, as derived in Table 123. If 32-year mean values are substituted in the table, the derived excess is 540 acre-feet.

TABLE 123. ESTIMATED ANNUAL EXCESS IN CUCAMONGA BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period				400
Items tending to decrease the drop				
Precipitation	15,870	15,460	410	
Surface inflow	7,870	7,450	420	
Import	4,340	3,840	500	
Subtotal to be subtracted				1,330
Items tending to increase the drop				
Consumptive use	15,710	15,130	580	
Export	10,240	10,060	180	
Surface outflow	1,080	1,200	—120	
Subtotal to be added				640
EXCESS				290

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must, in accordance with principles set forth in Chapter V, have averaged 760 acre-feet annually, as derived in Table 124.

TABLE 124. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM CUCAMONGA BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	15,460	
Surface inflow	7,450	
Import	3,840	
Water coming from storage in basin	400	
Subtotal		27,150
Water leaving basin on surface		
Surface outflow	1,200	
Export	10,060	
Consumptive use	15,130	
Subtotal		26,390
SUBSURFACE OUTFLOW—to Chino Basin		760

RIALTO BASIN (21a)

Rialto Basin is located in the north central portion of Upper Santa Ana Valley, and covers about 22 square miles. It is bounded on the southwest by Chino Basin, on the northwest by San Gabriel Mountains, on the northeast by Lytle Basin, and on the east by Colton Basin. Topography is regular, except in the north portion along the channel of Lytle Creek where it exhibits characteristics common to outwash areas. Slope is generally southerly, and ranges from 80 to 150 feet per mile, being steeper near the mountains. Elevations above sea level range from 1,150 at its southerly tip, to 2,250 feet at the mouth of Lytle Canyon. Soils are mostly lighter members of the Hanford series, and are quite receptive of moisture. Municipal development occupies less than 1 percent of the area, about 17 percent is devoted to agriculture, and the remainder is largely in a natural state.

The local water supply, utilized to a considerable extent through diversion from surface streams, but also through pumping from ground water, originates in precipitation on valley lands, and inflow from 36,660 acres of mountains directly tributary to the basin. Some water is imported.

A considerable part of surface inflow and precipitation flows out into Lytle and Chino Basins, together with some underflow into Chino Basin, and water is exported in relatively large amount to Chino, Colton and Lytle Basins.

Long-time mean annual net supply to Rialto Basin under present conditions is slightly less than present annual demand if the 21-year period is assumed to represent the long-time mean cycle of supply, and somewhat greater if the 32-year cycle is used, indicating an overdraft under one assumption and an excess under the other. Evaluation of items required* to estimate the amount of overdraft or excess follows.

Inflow

Estimated annual surface inflow averages 37,130 acre-feet, 35,190 acre-feet and 33,730 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 125.

Inflow from a portion of the directly tributary mountain area was measured at Station 19449 on Lytle Creek during the 11- and 21-year periods. The 32-year value is derived by comparison with San Antonio Creek.

The estimate of 32-year mean annual inflow from 6,180 acres of mountains directly tributary to the basin, and downstream from the gaging station at which above inflow was measured, is based on the assumption that average consumptive use on mountain area is 19 inches. The 11-year value is estimated to be 0.91 times the 32-year mean, this being the ratio between 11- and 32-year mean discharge of San Antonio Creek. The corresponding ratio for the 21-year period is 0.95.

It is assumed that the only subsurface inflow is that indicated by note in Table 125.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

TABLE 125. SURFACE INFLOW TO RIALTO BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Measured during part of period	32,210	30,510	29,240
Estimated [a]	4,920	4,680	4,490
Total	37,130	35,190	33,730

[a] Includes a relatively small amount of underflow.

Import

In Table 126 estimated values of imports of water from Lytle and Colton Basins for each year since 1927-28 are presented. No sewage is imported. During the 11-year period the import averaged 4,930 acre-feet annually. Estimated average annual import of water under present conditions is 5,720 acre-feet, equal to the average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 126. IMPORT TO RIALTO BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	6,270	1933-34	6,580	1939-40	5,570
1928-29	6,030	1934-35	3,990	1940-41	2,950
1929-30	4,910	1935-36	5,380	1941-42	5,450
1930-31	5,320	1936-37	3,670	1942-43	6,060
1931-32	3,740	1937-38	3,890	1943-44	6,110
1932-33	4,420	1938-39	6,870	1944-45	5,260

Consumptive Use

In Table 127 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. Only about 17 percent of the area is devoted to irrigated crops. Domestic development is small and there is no industrial development. A relatively small part of the unirrigated land is in grapes, the rest being covered in large part by light to medium brush, with some weeds and grass in lower portions of the basin.

TABLE 127. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN RIALTO BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley area					
Garden and field	1.4	37	52	22	31
Avocado and citrus	2.5	2,022	5,055	2,132	5,330
Deciduous	2.3	338	777	263	605
Domestic and industrial	1.8	95	171	100	180
Unirrigated	----	11,722	----	11,697	----
32-year period	1.6	----	----	----	18,715
21-year period	1.606	----	----	----	18,785
11-year period	1.594	----	18,685	----	----
Total	----	14,214	----	14,214	----
32-year period	----	----	----	----	24,861
21-year period	----	----	----	----	24,931
11-year period	----	----	24,740	----	----

Export

In Table 128 estimated exports of water for each year since 1927-28 are presented. There is no sewage outflow. Water is exported to Chino, Colton and Lytle Basins from both gravity and pumped sources. Gravity water from Fontana Power House not needed for use is released back into Lytle Creek channel, for spreading and percolation in Lytle Basin. During the 11-year period an annual average of 22,090 acre-feet of water was exported.

The amount of water exported depends to some extent upon the amount of gravity water available. Average annual release from the power house back to Lytle Creek channel is assumed to equal the average power diversion from Lytle Creek for the 21-year period, multiplied by the ratio between amount released and amount diverted for the period of dual record, 1926-27 through 1944-45. For that portion of export for direct use which appears to have correlation with the amount diverted from Lytle Creek, average annual export under present conditions is estimated to equal the average diversion for the 21-year period, multiplied by the ratio between average export and average diversion for the period of dual record available, 1927-28 through 1944-45. For the remainder, average annual export under present conditions is assumed to equal the average for the four-year period, 1941-42 to 1944-45, inclusive. Estimated present average annual export totals 25,000 acre-feet.

TABLE 128. EXPORT FROM RIALTO BASIN

Year	Acre-feet	Year	Acre-feet	Year	Acre-feet
1927-28	20,430	1933-34	15,690	1939-40	25,920
1928-29	15,090	1934-35	25,250	1940-41	35,730
1929-30	17,260	1935-36	20,320	1941-42	27,410
1930-31	15,130	1936-37	34,420	1942-43	34,580
1931-32	24,610	1937-38	35,550	1943-44	38,440
1932-33	19,210	1938-39	26,840	1944-45	31,760

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and runoff originating in precipitation on overlying valley land. It is estimated to average 8,550 acre-feet, 9,650 acre-feet and 10,210 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 129.

The greater part of inflow to this basin is in Lytle Creek, which flows in an unpaved and largely unconfined channel 4.5 miles along the northeasterly boundary, partly in Rialto Basin and partly in Lytle Basin. Water is diverted from Lytle Creek at the mouth of the canyon to develop power at the Fontana Power House, approximately two-thirds of the way down the basin. Discharge from the power house is used for irrigation when needed, either within the basin or by export, or is released back into Lytle Creek channel in Lytle Basin for spreading and percolation therein. The amount thus released is treated as export rather than outflow. It is believed that operation of extensive spreading grounds constructed on the upper Lytle Creek cone in 1925 and destroyed by the flood of March, 1938, had little effect on outflow during the 11-year period.

Discharge of Lytle Creek has been measured at Station 19449 just below the power diversion since 1918-19. Fontana Union Water Company has measured flow at several points downstream on the cone of the creek since March, 1938, from which data actual percolation between the power diversion and the junction with Cajon Creek has been determined. Percolation in this reach from 1918-19 to March, 1938, is estimated from a standard percolation curve which approximates observed percolation since March, 1938, and results in complete percolation up to 75 second-feet. Surface outflow from sources above Station 19449 is estimated for the 11- and 21-year periods from daily discharge measurements at the gaging station, using above percolation data, and assuming that 40 percent of percolation between the power diversion and junction with Cajon Creek occurs in Rialto Basin. For the 32-year period, annual runoff at Station 19449 prior to 1918-19 is estimated by comparison with San Antonio Creek. Yearly outflow from the basin prior to 1918-19 is then estimated from its relationship with runoff at Station 19449. Outflow from sources entering below the power diversion is estimated to be 50 percent of inflow from 2,340 acres of directly tributary mountains. Surface outflow from Rialto Basin in Lytle Creek enters Lytle Basin. Estimated outflow to Chino Basin includes 50 percent of inflow from about 1,460 acres and 90 percent from 1,740 acres of directly tributary mountains, and 2 percent of precipitation on tributary valley land within Rialto Basin.

TABLE 129. SURFACE OUTFLOW FROM RIALTO BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
All estimated			
To Lytle Basin, originating in			
Lytle Creek, above gaging station	5,320	6,570	7,250
Directly tributary mountains, below station	1,260	1,200	1,140
Subtotal	6,580	7,770	8,390
To Chino Basin, originating in			
Directly tributary mountains	1,580	1,490	1,440
Precipitation on valley land	390	390	380
Subtotal	1,970	1,880	1,820
Total	8,550	9,650	10,210

Overdraft

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual overdraft is 220 acre-feet, as derived in Table 130. If 32-year mean values are substituted in the table, an annual excess of 2,670 acre-feet is indicated.

TABLE 130. ESTIMATED ANNUAL OVERDRAFT IN RIALTO BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period	----	----	----	340
Items tending to increase the drop				
Consumptive use	24,930	24,740	190	
Surface outflow	9,650	10,210	—560	
Export	25,000	22,090	2,910	
Subtotal to be added				2,540
Items tending to decrease the drop				
Precipitation	25,010	24,600	410	
Surface inflow	35,190	33,730	1,460	
Import	5,720	4,930	790	
Subtotal to be subtracted				2,660
OVERDRAFT				220

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must, in accordance with principles set forth in Chapter V, have averaged 6,560 acre-feet annually, as derived in Table 131.

TABLE 131. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM RIALTO BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	24,600	
Surface inflow	33,730	
Import	4,930	
Water coming from storage in basin	340	
Subtotal		63,600
Water leaving basin on surface		
Surface outflow	10,210	
Export	22,090	
Consumptive use	24,740	
Subtotal		57,040
SUBSURFACE OUTFLOW—to Chino Basin		6,560

LOWER CAJON BASIN (40)

Lower Cajon Basin is located in the extreme northerly portion of Upper Santa Ana Valley, and covers about 6.9 square miles. It is bounded on the west and southwest by San Gabriel Mountains, on the northeast and east by San Bernardino Mountains, on the southeast by Devil Canyon Basin, and on the south by Bunker Hill Basin and Shandin Hills. Topography is irregular, the result of alternate deposition and cutting by Cajon Creek, and by numerous small, flashy streams entering from mountains on the northeast and southwest. The slope, in the southeasterly direction of flow of Cajon Creek, averages about 100 feet per mile, but is much steeper immediately adjacent to the mountains. Elevations range from 1,750 to more than 2,550 feet above sea level. Soils covering this basin are mostly lighter members of the Hanford and Tujunga series, with a few small areas of light Ramona and Placentia soils, and a considerable area of river wash along Cajon Creek. All are quite absorptive. There is no municipal development and only 8 percent of the area is devoted to agriculture, the remaining 92 percent being largely in a natural state.

The local water supply, utilized largely through diversion from springs, and to a minor extent through pumping from ground water, originates in precipitation on valley lands, inflow from 10,890 acres of mountains directly tributary to the basin, and inflow largely on the surface from Upper Cajon Basin, all of the last named as flood flow and rising water in Cajon and Lone Pine Creeks. There is no import of water or sewage.

A considerable part of the surface inflow and precipitation on the valley flows out into Devil Canyon and Bunker Hill Basins, together with large underflow to the latter. Pumped water has been exported to Bunker Hill Basin since 1940-41.

Long-time mean annual supply entering Lower Cajon Basin under present conditions is much greater than present annual demand. Along its lower boundary, however, there is no effective barrier to underflow into Bunker Hill Basin. For this reason water, which might constitute an excess if such a barrier existed, soon leaves the basin as underflow, and it is this underflow to downstream basins which is herein estimated. Evaluation of items required * to estimate its long-time mean amount follows.

Inflow

Estimated annual surface inflow averages 17,400 acre-feet, 15,230 acre-feet and 15,150 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 132.

Inflow from Upper Cajon Basin has been measured at gaging Station 19433B on Cajon Creek since 1920-21, and at Station 19433A on Lone Pine Creek during the period from 1920-21 to 1937-38, inclusive. Thirty-two year values for both streams, and the 21-year value for Lone Pine Creek, are derived by comparison with Lytle and San Antonio Creeks.

The estimate of 32-year mean annual inflow from 10,890 acres of mountains directly tributary to the basin, and downstream from gaging stations at which above inflow was measured, is based on the assumption that average consumptive use on the northwesterly 7,040 acres of this mountain area is 20 inches while that on the southeasterly 3,850 acres, with greater indicated average precipitation, is 22 inches. The 11-year value is estimated to be 0.79 times the 32-year mean, this being the ratio between 11- and 32-year mean discharge of Santa Ana River. The corresponding ratio for the 21-year period is 0.80.

It is assumed that the only subsurface inflow is that indicated by note in Table 132.

TABLE 132. SURFACE INFLOW TO LOWER CAJON BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
From other basins			
Measured during part of period	8,060	7,760	7,770
From directly tributary mountains			
Estimated [a]	9,340	7,470	7,380
Total	17,400	15,230	15,150

[a] Includes a relatively small amount of underflow.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Consumptive Use

In Table 133 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. A relatively small part of the area is used. There is little domestic and no industrial development, but about 7 percent of the area, bench land east of Cajon Creek, is devoted to deciduous fruits, and there is a small area of irrigated grass. Most of the remainder of the area is covered with brush.

TABLE 133. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN LOWER CAJON BASIN

Type of culture	*Unit consumptive use, feet*	*1932 Acres*	*1932 Acre-feet*	*1942 Acres*	*1942 Acre-feet*
Valley area					
Deciduous	2.3	310	713	310	713
Irrigated grass	3.0	55	165	55	165
Unirrigated	----	4,065	----	4,065	----
32-year period	1.7	----	----	----	6,910
21-year period	1.707	----	----	----	6,939
11-year period	1.693	----	6,882	----	----
Subtotal	----	4,430	----	4,430	----
32-year period	----	----	----	----	7,788
21-year period	----	----	----	----	7,817
11-year period	----	----	7,760	----	----

Export

In Table 134 estimated values of export of water to Bunker Hill Basin, for each year since 1940-41 when export started, are presented. There is no sewage outflow. During the 11-year period, no water was exported. Estimated average annual export of water under present conditions is 2,070 acre-feet, equal to its 1943-44 value.

TABLE 134. EXPORT FROM LOWER CAJON BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*
1940-41	1,000	1943-44	2,070
1941-42	1,530	1944-45	2,120
1942-43	1,640		

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains, a part of that from Upper Cajon Basin and runoff originating in precipitation on the overlying valley. It is estimated to average 5,040 acre-feet, 5,200 acre-feet and 5,240 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 135.

Flows in Cajon and Lone Pine Creeks combine near the upper boundary of Lower Cajon Basin and flow approximately 6.5 miles in the natural channel of Cajon Creek, before entering Bunker Hill Basin. The two streams were measured at Stations 19433B and 19433A, respectively, during the period 1920-21 to 1937-38, inclusive. After the latter year only Cajon Creek was measured. Daily discharges at Station 19433A since 1938-39 are estimated by comparison with Cajon Creek. The measured and estimated daily discharges and a percolation curve which results in complete percolation up to 84 second-feet are used to estimate outflow of water originating above the gaging stations for each year since 1920-21. Annual inflows at the two stations prior to that year are estimated by comparison with San Antonio Creek and corresponding annual outflows by comparison with the inflows.

Estimated surface outflow to Bunker Hill Basin originating below the gaging stations consists of 25 percent of the inflow from 7,580 acres of directly tributary mountains, and 2 percent of the precipitation on 2,550 acres of overlying valley land. Estimated surface outflow to Devil Canyon Basin consists of 50 percent of the inflow from 3,310 acres of directly tributary mountains and 2 percent of the precipitation of 1,880 acres of overlying valley land.

TABLE 135. SURFACE OUTFLOW FROM LOWER CAJON BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Estimated			
To Bunker Hill Basin, originating in			
Inflow from other basins	1,500	2,330	2,400
Directly tributary mountains	1,350	1,080	1,070
Precipitation on valley land	120	120	120
Subtotal	2,970	3,530	3,590
To Devil Canyon Basin, originating in			
Directly tributary mountains	1,970	1,570	1,550
Precipitation on valley land	100	100	100
Subtotal	2,070	1,670	1,650
Total	5,040	5,200	5,240

Subsurface Outflow

All water which enters Lower Cajon Basin, including its overlying area, during any period, must either go into storage within the boundaries of the basin, be consumed or exported, or flow out either on the surface or underground. Since 32-, 21- and 11-year average values have been estimated for all but the last item, i.e., subsurface outflow, its value is determined as shown in Table 136. Because a relatively greater amount of stream flow data is available during the 21-year period, it is assumed to be the cycle of long-time mean supply, and estimated long-time mean annual subsurface outflow under present conditions is 11,330 acre-feet.

TABLE 136. ESTIMATED SUBSURFACE OUTFLOW FROM LOWER CAJON BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Water entering basin			
Precipitation	11,090	11,190	11,000
Surface inflow	17,400	15,230	15,150
Subtotal	28,490	26,420	26,150
Change in storage	0	0	0
Water leaving basin on surface			
Surface outflow	5,040	5,200	5,240
Export	2,070	2,070	0
Consumptive use	7,790	7,820	7,760
Subtotal	14,900	15,090	13,000
SUBSURFACE OUTFLOW—to Bunker Hill Basin	13,590	11,330	13,150

LYTLE BASIN (23)

Lytle Basin is located in the north central portion of Upper Santa Ana Valley, and covers about 6.2 square miles. It is bounded on the southwest by Rialto and Colton Basins, on the north by San Gabriel Mountains, and on the northeast, east and south by Bunker Hill Basin. The basin is about seven miles long and averages about a mile wide. Its upper two-thirds is covered by outwash from Lytle and Cajon Creeks, and the topography is characteristically cut by innumerable small channels. In the lower portion cutting is deeper, and irregularities are fewer but more pronounced. Slope varies from 75 to 200 feet per mile, and is generally to the southeast. Elevations above sea level range from 1,180 to about 2,100 feet. Soils include lighter members of the Hanford and Tujunga series, and river wash materials all of which are quite absorptive. There is no municipal development in this basin. Only about 2 percent of the area is devoted to agriculture, and the remaining 98 percent is largely in a natural state.

The local water supply; utilized almost entirely through pumping from ground water, originates in precipitation on valley lands, inflow from 1,550 acres of mountains directly tributary to the basin, and surface inflow from Rialto and Bunker Hill Basins in Lytle Creek and Cajon Creek, respectively. Interconnection between Lytle and Bunker Hill Basins is such that underflow may be in one direction at one point, and the opposite at another. Net flow may also be in one direction at one time and the reverse at another. Imported water, part of which passes through the basin, provides a relatively large addition to the supply.

A considerable part of the surface inflow flows out into Bunker Hill Basin, and water is exported in large amount to Colton, Rialto, Bunker Hill and Chino Basins.

Due to increased export in recent years, average annual demand under present conditions is somewhat greater than mean annual supply. Because storage capacity is so limited that neither overdraft nor excess can continue for any considerable period of time, the average annual amount that can be exported under present conditions, without exceeding supply over a long-time cycle, is estimated herein. Evaluation of items required* for the estimate follows.

Inflow

Estimated annual surface inflow averages 9,510 acre-feet, 11,340 acre-feet and 12,100 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 137.

The estimate of annual inflow from 1,550 acres of mountains directly tributary to the basin is based on the assumption that, if water is available, average consumptive use on the mountain area is 20 inches. The 11- and 21-year values are estimated to be 0.79 and 0.80 times the 32-year mean, respectively, these being the ratios between the 11- and 21-year averages and the 32-year mean discharge of Santa Ana River.

Inflow on the surface from other basins includes a part of the surface outflow from Rialto and Bunker Hill Basins.

It is assumed that only subsurface inflow is that indicated by note in Table 137.

TABLE 137. SURFACE INFLOW TO LYTLE BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
From directly tributary mountains			
Estimated [a]	1,360	1,080	1,070
From other basins			
Rialto	6,580	7,770	8,390
Bunker Hill	1,570	2,490	2,640
Total [a]	9,510	11,340	12,100

[a] Includes a relatively small amount of underflow.

Import

In Table 138 estimated values of imports of water from both gravity and pumped sources in Rialto Basins for each year since 1927-28 are presented. No sewage is imported. Values of import given include releases from Fontana Power House for spreading in Lytle Creek channel. During the 11-year period an annual average of 10,520 acre-feet was imported.

The amount of gravity water imported depends to some extent upon the amount available. Diversions to and releases from the power house have been measured since 1918-19 and 1926-27 respectively. Average

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

annual release from the power house back to Lytle Creek channel is assumed to equal the average power diversion from Lytle Creek for the 21-year period, multiplied by the ratio between amount released and amount diverted since 1926-27. Assuming the import of pumped water equal to the average for the four-year period, 1941-42 to 1944-45, inclusive, estimated long-time mean import to Lytle Basin under present conditions totals 10,620 acre-feet annually.

TABLE 138. IMPORT TO LYTLE BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	10,800	1933-34	7,140	1939-40	11,170
1928-29	7,060	1934-35	12,700	1940-41	18,950
1929-30	9,270	1935-36	6,530	1941-42	12,540
1930-31	7,850	1936-37	15,940	1942-43	12,990
1931-32	11,930	1937-38	16,690	1943-44	12,400
1932-33	9,830	1938-39	11,370	1944-45	13,110

Consumptive Use

In Table 139 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. The many small channels of Lytle Creek cover virtually the entire area. Largely because of this there is no municipal development, the acreage devoted to agriculture is small, and most of the area remains in its natural state. Cover ranges from moderately heavy brush to grass.

TABLE 139. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN LYTLE BASIN

Type of culture	*Unit consumptive use, feet*	*1932*		*1942*	
		Acres	*Acre-feet*	*Acres*	*Acre-feet*
Valley area					
Avocado and citrus	2.5	63	158	63	158
Deciduous	2.3	42	97	27	62
Unirrigated	----	3,843	----	3,858	----
32-year period	1.7	----	----	----	6,559
21-year period	1.707	----	----	----	6,586
11-year period	1.693	----	6,506	----	----
Subtotal	----	3,948	----	3,948	----
32-year period	----	----	----	----	6,779
21-year period	----	----	----	----	6,806
11-year period	----	----	6,761	----	----
Mountain area					
Deciduous	0.6 [a]	115	69	0	0
Grand total	----	4,063	----	3,948	----
32-year period	----	----	----	----	6,779
21-year period	----	----	----	----	6,806
11-year period	----	----	6,830	----	----

[a] Difference between irrigated culture and natural vegetation.

Historical Export

In Table 140 estimated exports of water for each year since 1927-28 are presented. There is no sewage outflow. Water is exported to Chino, Rialto, Colton and Bunker Hill Basins. Export includes both water pumped from the basin and imported water. During the 11-year period an annual average of 13,450 acre-feet was exported.

TABLE 140. EXPORT FROM LYTLE BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	19,500	1933-34	15,460	1939-40	17,420
1928-29	19,830	1934-35	10,710	1940-41	10,300
				1941-42	18,370
1930-31	13,970	1936-37	9,020	1942-43	18,560
1931-32	9,260	1937-38	9,270	1943-44	16,770
1932-33	11,630	1938-39	17,230	1944-45	19,180

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains, part of that from other basins, part of the Fontana Power House release and runoff originating in precipitation on the overlying valley.

Daily discharges in East and West Branches of Lytle Creek have been measured at Stations 17980 and 17982, respectively, since January, 1929. Fontana Union Water Company has measured daily discharges in Lytle Creek at Station 18769 continuously since March 5, 1938, and intermittently at Station 18767, at the basin boundary, since that date. These latter data have been used to determine a curve which represents average percolation rates between the basin boundary and Foothill Boulevard. It is assumed that there was little or no percolation below Foothill Boulevard, since it is close to the limit of the pressure area.

Surface outflow from the basin, for the period from January, 1929, through March 4, 1938, is estimated by use of the above percolation curve and daily discharges at gaging stations 17980 and 17982. Surface outflow subsequent to March 4, 1938, for days when not measured at Station 18767, is estimated by use of the percolation curve and daily discharges measured at Station 18769.

Surface outflow prior to January, 1929, is estimated from measured and estimated yearly runoff in Lytle Creek at Station 19449, using relationship of outflow to runoff established during subsequent years. Yearly runoff at Station 19449, prior to beginning of record in 1918-19, is estimated by comparison with San Antonio Creek.

On this basis, average annual surface outflow for the 32-year period is estimated to be 2,210 acre-feet; for the 21-year period, 4,060 acre-feet; and for the 11-year period, 5,430 acre-feet.

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period must, in accordance with principles set forth in Chapter V, have averaged 590 acre-feet annually, as derived in Table 141.

TABLE 141. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM LYTLE BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	7,140	
Surface inflow	12,100	
Import	10,520	
Subtotal		29,760
Water leaving basin on the surface		
Surface outflow	5,430	
Export	13,450	
Consumptive use	6,830	
Increase in storage	3,460	
Subtotal		29,170
SUBSURFACE OUTFLOW—to Bunker Hill Basin		590

Long-time Mean Amount Available for Export

The hydrologic equation used in the foregoing article applies equally well in any period. If safe yield of the basin is fully utilized, with neither excess nor overdraft, net change in storage over a cycle of long-time mean supply is zero. Assuming that subsurface outflow is the same for all periods, all items involved, except export, have been evaluated for both 32- and 21-year cycles. Assuming the 21-year period to represent the cycle of long-time mean supply, estimated long-time mean annual amount available for export is 17,760 * acre-feet, as derived in Table 142. If the 32-year values are substituted the derived value is 17,750 acre-feet.

TABLE 142. ESTIMATED AVERAGE ANNUAL AMOUNT AVAILABLE FOR EXPORT FROM LYTLE BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	
Supply to basin		
Precipitation	7,260	
Import	10,620	
Surface inflow	11,340	
Subtotal		29,220
Demand on basin, excluding export		
Consumptive use	6,810	
Surface outflow	4,060	
Subsurface outflow	590	
Subtotal		11,460
AVAILABLE FOR EXPORT		17,760

* There is some evidence tending to justify establishing the boundary between Lytle and Rialto Basins west of Lytle Creek throughout its length. It is estimated that 30,600 acre-feet of water per year is available for export from the area which would constitute Lytle Basin if this were done. Calculated overdraft on Rialto Basin would not be affected by the change.

DEVIL CANYON BASIN (24)

Devil Canyon Basin is located in the north central portion of Upper Santa Ana Valley, and covers about 9.9 square miles. It is bounded on the south and southwest by Bunker Hill Basin and Shandin Hills, on the northwest by Lower Cajon Basin, and on the north and northeast by San Bernardino Mountains. Topography is irregular, the result of alternate deposition and cutting by numerous small, flashy streams entering from mountains on the northeast. Slope is generally to the south and averages about 200 feet per mile, being steeper immediately adjacent to the mountains. Elevations range from 1,285 to more than 2,200 feet above sea level. Soils covering this basin are mostly lighter members of the Hanford and Tujunga series, with a few small areas of light Placentia and Holland soils. All are quite absorptive. Municipal development occupies only about 4 percent of the area, about 6 percent is devoted to agriculture, and the remaining 90 percent is largely in a natural state.

The local water supply, utilized both through pumping from ground water, and by diversion from surface streams, originates in precipitation on the valley, inflow from 17,700 acres of mountains and 720 acres of hills directly tributary to the basin, and inflow on the surface from Lower Cajon Basin. There is no import of water or sewage.

A considerable part of the surface inflow and a smaller part of the precipitation on the valley flows out into Bunker Hill Basin, together with large underflow, and water is exported in relatively large amount to the same basin.

Long-time mean annual supply entering Devil Canyon Basin under present conditions is materially greater than present annual demand. Along its south boundary, however, there is no effective barrier to underflow into Bunker Hill Basin. For this reason it is assumed that water, which might constitute an excess if such a barrier existed, soon leaves the basin as underflow, and it is the long-time mean amount of this subsurface outflow to downstream basins which is estimated herein. Evaluation of items required * for the estimate follows.

Inflow

Annual inflow from directly tributary mountain area above gaging stations at which flow has been measured during a part of each period, is tabulated below. The 32-year mean values for Waterman Canyon Creek and Strawberry Creek were computed by comparison with Santa Ana River. Values for all three periods for Devil Canyon Creek were estimated by comparison with Waterman Canyon Creek.

		Mean annual inflow[a] in acre-feet		
Stream	*Station*	*32-year period*	*21-year period*	*11-year period*
Devil Canyon Creek	19569	2,810	2,180	2,030
Waterman Canyon Creek	18820	2,600	1,930	1,790
Strawberry Creek	18832	4,430	3,520	3,040
Total		9,840	7,630	6,860

[a] Including diversions.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

The estimate of 32-year mean annual inflow from 5,660 acres of mountains and 720 acres of hills directly tributary to the basin, and downstream from gaging stations at which the above tabulated inflow was measured is based on the assumption that average consumptive use on mountain area is 20 inches, and that on hill area 19 inches. Average inflow from the mountains during the 11-year period is estimated to be 0.79 times the 32-year mean, this being the ratio between 11- and 32-mean discharge of Santa Ana River. That from the hills is estimated to be 0.99 times the 32-year mean, being proportional to precipitation on the area represented by the San Bernardino Group. Corresponding ratios for the 21-year period are 0.80 for mountains and 1.01 for hills.*

A small part of surface outflow from Lower Cajon Basin enters Devil Canyon Basin. It is assumed that the only subsurface inflow is that indicated by note in the table.

TABLE 143. SURFACE INFLOW TO DEVIL CANYON BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	21-year period	11-year period
From directly tributary mountains			
Measured during part of period	9,840	7,630	6,860
Estimated [a]	2,330	1,860	1,840
From directly tributary hills			
Estimated [a]	240	240	240
From other basins			
Lower Cajon	2,060	1,670	1,650
Total	14,470	11,400	10,590

[a] Includes a relatively small amount of underflow.

Consumptive Use

In Table 144 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. A relatively small part of the area is used. The City of San Bernardino extends into the easterly end, and something less than 6 percent of the total is devoted to irrigated agriculture. Some unirrigated lands are used for spreading, grapes occupy a part, and most of the remainder is covered with brush.

* If inflow from hills is assumed to follow the same regimen of flow as Santa Ana River, average for both 21- and 11-year periods is 190 acre-feet.

TABLE 144. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN DEVIL CANYON BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley area					
Garden and field	1.4	30	42	125	175
Avocado and citrus	2.5	227	568	212	530
Deciduous	2.3	125	288	35	80
Domestic and industrial	1.8	188	338	263	473
Unirrigated	----	5,745	----	5,680	----
32-year period	1.7	----	----	----	9,656
21-year period	1.707	----	----	----	9,696
11-year period	1.693	----	9,726	----	----
Subtotal	----	6,315	----	6,315	----
32-year period	----	----	----	----	10,914
21-year period	----	----	----	----	10,954
11-year period	----	----	10,962	----	----
Mountain area					
Avocado and citrus	0.9[a]	22	20	22	20
Grand total	----	6,337	----	6,337	----
32-year period	----	----	----	----	10,934
21-year period	----	----	----	----	10,974
11-year period	----	----	10,982	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 145 estimated exports of water to Bunker Hill Basin for each year since 1927-28 are presented. There is no sewage outflow. During the 11-year period an annual average of 1,930 acre-feet of water was exported. Estimated average annual export of water under present conditions is 3,170 acre-feet, equal to the average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 145. EXPORT FROM DEVIL CANYON BASIN

Year	Acre-feet	Year	Acre-feet	Year	Acre-feet
1927-28	2,300	1933-34	1,400	1939-40	2,620
1928-29	1,900	1934-35	1,140	1940-41	3,140
1929-30	2,380	1935-36	1,280	1941-42	2,140
1930-31	1,630	1936-37	2,300	1942-43	3,210
1931-32	1,920	1937-38	2,920	1943-44	3,660
1932-33	2,080	1938-39	3,140	1944-45	3,670

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and hills, part of that from Lower Cajon Basin, and runoff originating in precipitation on the overlying valley. It is estimated to average 5,200 acre-feet, 4,100 acre-feet and 4,250 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 146.

Inflow from mountains directly tributary to this basin is well distributed in several streams, the larger being Devil Canyon, Waterman Canyon and Strawberry Creeks. None of the channels are paved, and there are spreading grounds on Devil Canyon and Waterman Canyon Creeks.

DEVIL CANYON CREEK

To estimate historic outflow in this stream during the 11-year period, 30 second-feet, assumed to be spread, is first subtracted from the measured daily discharge at Station 19569. Estimated percolation below the spreading grounds, using a standard curve which results in total percolation up to 23 second-feet, is then subtracted from the discharge below the spreading grounds. Average annual outflow during the 11-year period, as estimated, is 160 acre-feet.

Under a plan which contemplates the early construction of an overflow channel through the low hills to the southwest, percolation below the spreading grounds is virtually eliminated. Outflow during each year since 1933-34, when measurements of diversion above the gaging station started, is estimated by subtracting 30 second-feet from the discharge at the station. To estimate outflow in earlier years the relationships (1) between annual outflow and net annual flow at the gaging station, and (2) between annual diversions and full natural annual inflow, as established since 1933-34, are used. Full natural inflow in the earlier years is estimated by comparison with Waterman Canyon Creek and Santa Ana River, diversions determined from relationship (2), net discharges at the station obtained by subtraction, and outflow finally derived from relationship (1). Estimated 32- and 21-year mean annual outflows so obtained are 240 and 150 acre-feet respectively.

WATERMAN CANYON CREEK

Discharge of Waterman Canyon Creek has been measured at Station 18820 since 1920-21. Assuming that 12 second-feet was diverted for spreading and direct use, estimated 11-year average annual outflow was 440 acre-feet.

The spreading grounds have been enlarged in recent years, and are now being extended further to provide flood protection as well as water conservation. To estimate outflow from the basin under present conditions during 32- and 21-year periods, it is arbitrarily assumed that 150 second-feet are diverted to spreading, and that all discharge in excess of that amount passes from the basin. Using the relationship between annual inflow and outflow established during the period of record, and estimated values of run-off for years prior to 1920-21 computed by comparison with Santa Ana River, outflow for years prior to beginning of record is estimated. The resulting mean annual outflow is 60 and 30 acre-feet in the 32- and 21-year periods respectively.

STRAWBERRY CREEK

Discharge of Strawberry Creek has been measured at Station 18832 since 1920-21. Allowing for a small diversion by Del Rosa Water Company, and using a percolation curve which results in total percolation up to three second-feet, 21- and 11-year average annual outflows are estimated to be 1,690 and 1,460 acre-feet, respectively. Determining inflow for years of no record by comparison with Santa Ana River, and using the relationship between inflow and outflow established during years of record, estimated 32-year mean annual outflow is 2,240 acre-feet.

OTHER SOURCES

Estimated outflow from other sources includes 90 percent of the inflow from 400 acres and 50 percent of that from 5,270 acres of directly tributary mountains, 75 percent of that from all hills directly tributary to the basin, 50 percent of that from Lower Cajon Basin, and 2 percent of precipitation on overlying valley land.

TABLE 146. SURFACE OUTFLOW FROM DEVIL CANYON BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Estimated, originating in			
Measured mountain streams [a]	2,540	1,870	2,060
Directly tributary mountains	1,210	970	950
Directly tributary hills	180	180	180
Inflow from other basins	1,030	840	820
Precipitation on valley land	240	240	240
Total	5,200	4,100	4,250

[a] From daily discharges, spreading and percolation.

Subsurface Outflow

In accordance with principles set forth in Chapter V, historic average annual subsurface outflow during the 11-year period, and present long-time mean annual subsurface outflow under two assumptions as to cycle of long-time mean supply, are derived in Table 147. Since a relatively greater amount of stream-flow data is available during the 21-year period, estimated long-time mean subsurface outflow under present conditions is 5,160 acre-feet.

TABLE 147. ESTIMATED SUBSURFACE OUTFLOW FROM DEVIL CANYON BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Water entering basin			
Precipitation	11,890	12,000	11,800
Surface inflow	14,470	11,400	10,590
Subtotal	26,360	23,400	22,390
Increase in storage	0	0	1,280
Water leaving basin on surface			
Surface outflow	5,200	4,100	4,250
Export	3,170	3,170	1,930
Consumptive use	10,930	10,970	10,980
Subtotal	19,300	18,240	18,440
SUBSURFACE OUTFLOW—to Bunker Hill Basin	7,060	5,160	3,950

YUCAIPA BASIN (25a)

Yucaipa Basin is located in the easterly portion of Upper Santa Ana Valley, and covers about 28 square miles. It is bounded on the southwest by San Timoteo Basin, on the northwest by Bunker Hill Basin and granitic hills, on the northeast by San Bernardino Mountains, and on the southeast and south by Beaumont Basin. Topography is irregular, cut by numerous deeply incised channels. The slope to the southwest averages about 250 feet per mile. Elevations above sea level range from 2,000 to 5,000 feet. Soils are mostly lighter members of the Placentia series, with relatively narrow areas of light Hanford soils along stream channels. While Placentia soils are less pervious than those of the Hanford series, they are still quite absorptive. Municipal development occupies only about 2 percent of the area, about 26 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on the valley, and inflow from 4,260 acres of mountains and 8,360 acres of hills directly tributary to the basin. There is no import of water or sewage.

A considerable part of the surface inflow and precipitation flows out into San Timoteo Basin, together with some underflow, and water is exported in relatively large amount to the same basin.

In this basin, long-time mean annual net supply under present conditions is less than present annual demand, so an overdraft exists. Evaluation of items required * to estimate its amount follows.

Inflow

Estimated annual surface inflow averages 5,960 acre-feet, 5,270 acre-feet and 5,200 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 148.

The estimate of 32-year mean annual inflow from 4,260 acres of mountains and 8,360 acres of hills directly tributary to the basin is based on the assumption that, if water is available, average consumptive use on mountain area is 22 inches and that on hill area 18 inches, inflow values however being never less than 7 percent of precipitation on mountains and 9 percent of that on hills. The 11-year value for mountains is estimated to be 0.79 times the 32-year mean, this being the ratio between 11- and 32-year mean discharge of Santa Ana River. That for the hills is estimated to be 0.99 times the 32-year mean, being proportional to precipitation on the area represented by the San Bernardino Group. Corresponding ratios for the 21-year period are 0.80 for the mountains and 1.01 for the hills.†

Subsurface inflow is assumed to be only that indicated by note in Table 148.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

† If inflow from the hills is assumed to follow the same regimen of flow as Santa Ana River, estimated annual inflow from that source is 1,920 and 1,900 acre-feet during 21- and 11-year periods, respectively.

TABLE 148. SURFACE INFLOW TO YUCAIPA BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Estimated, originating in			
Directly tributary mountains	3,560	2,850	2,820
Directly tributary hills	2,400	2,420	2,380
Total [a]	5,960	5,270	5,200

[a] Includes a relatively large but undetermined amount of underflow.

Consumptive Use

In Table 149 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. Domestic development is relatively small and industry negligible. Because of the climate at this altitude, deciduous orchards and gardens constitute the principal crops. Cover on unirrigated lands ranges from heavy brush to grass and weeds.

TABLE 149. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN YUCAIPA BASIN

Type of culture	*Unit consumptive use, feet*	*1932* Acres	*1932* Acre-feet	*1942* Acres	*1942* Acre-feet
Valley and folded area					
Garden and field	1.4	272	381	1,017	1,424
Avocado and citrus	2.7	209	564	404	1,091
Deciduous	2.3	4,362	10,033	3,017	6,939
Alfalfa	3.0	71	213	96	288
Domestic and industrial	1.8	195	351	390	702
Unirrigated	----	12,521	----	12,706	----
32-year period	1.5	----	----	----	19,059
21-year period	1.506	----	----	----	19,135
11-year period	1.494	----	18,706	----	----
Subtotal	----	17,630	----	17,630	----
32-year period	----	----	----	----	29,503
21-year period	----	----	----	----	29,579
11-year period	----	----	30,248	----	----
Hill area					
Avocado and citrus	1.2[a]	17	20	17	20
Deciduous	0.8[a]	130	104	135	108
Subtotal	----	147	124	152	128
Grand total	----	17,777	----	17,782	----
32-year period	----	----	----	----	29,631
21-year period	----	----	----	----	29,707
11-year period	----	----	30,372	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 150 estimated exports of water to San Timoteo Basin for each year since 1927-28 are presented. There is no sewage outflow. During the 11-year period, an annual average of 1,440 acre-feet of water was exported. Estimated average annual export of water under present conditions is 1,420 acre-feet, equal to the average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 150. EXPORT FROM YUCAIPA BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	1,410	1933-34	1,670	1939-40	1,580
1928-29	1,490	1934-35	1,140	1940-41	1,240
1929-30	1,560	1935-36	1,560	1941-42	1,520
1930-31	1,600	1936-37	1,330	1942-43	1,400
1931-32	1,220	1937-38	1,370	1943-44	1,350
1932-33	1,470	1938-39	1,430	1944-45	1,400

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and hills and runoff originating in precipitation on the overlying valley. It is estimated to average 1,470 acre-feet, 1,320 acre-feet and 1,300 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 151.

Geological investigations indicate that a considerable part of the estimated inflow to this basin from the mountains reaches the valley as underflow. Surface flow is distributed in several small streams which, except those tributary to Bunker Hill Basin, flow from six to ten miles across Yucaipa Basin. None of these stream channels are paved, and there is considerable percolation opportunity. Directly tributary hills are also for the most part some distance from the basin boundary.

It is estimated that outflow from this basin includes 90 percent of the inflow from 1,120 acres of mountains and 140 acres of hills adjacent to Bunker Hill Basin, 10 percent of the inflow from remaining directly tributary mountains and hills, 5 percent of the precipitation on 2,320 acres of basin land classified as folded, and 1 percent of the precipitation on other valley land.

TABLE 151. SURFACE OUTFLOW FROM YUCAIPA BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Estimated, originating in			
Directly tributary mountains	790	640	630
Directly tributary hills	260	260	250
Precipitation on valley and folded area	420	420	420
Total	1,470	1,320	1,300

Overdraft

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual overdraft is 1,150 acre-feet, as derived in Table 152. If the 32-year mean values are substituted in the table the derived value is 790 acre-feet.

TABLE 152. ESTIMATED ANNUAL OVERDRAFT IN YUCAIPA BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period	----	----	----	2,350
Items tending to increase the drop				
Consumptive use	29,710	30,370	—660	
Surface outflow	1,320	1,300	20	
Export	1,420	1,440	—20	
Subtotal to be added				—660
Items tending to decrease the drop				
Precipitation	28,950	28,480	470	
Surface inflow	5,270	5,200	70	
Subtotal to be subtracted				540
OVERDRAFT				1,150

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period must, in accordance with principles set forth in Chapter V, have averaged 2,920 acre-feet annually, as derived in Table 153.

TABLE 153. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM YUCAIPA BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	28,480	
Surface inflow	5,200	
Water coming from storage in basin	2,350	
Subtotal		36,030
Water leaving basin on surface		
Surface outflow	1,300	
Export	1,440	
Consumptive use	30,370	
Subtotal		33,110
SUBSURFACE OUTFLOW—to San Timoteo Basin		2,920

BEAUMONT BASIN (25b)

Beaumont Basin is located in the extreme east end of Upper Santa Ana Valley, and covers about 31 square miles. It is bounded on the west by San Timoteo Basin, on the north and northwest by Yucaipa Basin, on the north by San Bernardino Mountains, on the southeast by the watershed of Whitewater River, and on the south by the watershed of San Jacinto River. Topography is irregular with deeply incised channels. Slope is to the south and southwest, and ranges from 100 to 600 feet per mile. Elevations above sea level range from 2,300 to 5,500 feet. Soils are about equally divided between lighter members of the Placentia and Hanford series, both of which are quite absorptive. Municipal development occupies only about 3 percent of the area, about 13 percent is devoted to agriculture, and the remaining 84 percent is in a more or less natural state.

The local water supply, utilized through diversion from surface streams, and through pumping from ground water, originates in precipitation on the valley, and inflow from 1,550 acres of mountains and 8,320 acres of hills directly tributary to the basin. There is no import of water or sewage.

A considerable part of the surface inflow and precipitation flows out into San Timoteo Basin, together with some underflow. Water is exported in relatively large amount to San Timoteo Basin, from which the major portion is re-exported to San Jacinto Valley.

Under terms of the Yucaipa Judgment,* the amount of water that may be pumped for export from the basin is dependent upon elevation of the water table at Well No. E-233f, Plate 15, decreasing as the water table drops, and vice versa. Thus a possible overdraft is counterbalanced by decreased export and a possible excess by a corresponding increase. It is therefore considered that there is neither excess nor overdraft in the basin and the average annual amount that can be exported without causing an overdraft, under present conditions over a long-time cycle of supply, is estimated herein. While it is believed that the result obtained by another method, described in the closing paragraphs of this section is probably more accurate, evaluation of items required † for an estimate through the use of the hydrologic equation follows.

Inflow

Estimated annual surface inflow averages 6,100 acre-feet, 5,750 acre-feet and 5,650 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 154.

The estimate of 32-year mean annual inflow from 1,550 acres of mountains and 8,320 acres of hills directly tributary to the basin is based on the assumption that, if water is available, average consumptive use on mountain area is 22 inches, and that on hill area 17 inches. Eleven-year average inflow from mountains is estimated to be 0.79 times the 32-year mean, this being the ratio between 11- and 32-year mean discharge of Santa Ana River. That from the hills is 0.99 times the 32-year mean, being proportional to precipitation on the area represented by the San

* Case No. 24570, San Bernardino County, May 7, 1929.
† Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Bernardino Group. Corresponding ratios for the 21-year period are 0.80 for mountains and 1.01 for hills.†

Subsurface inflow, other than that indicated by note in Table 154, is negligible.

TABLE 154. SURFACE INFLOW TO BEAUMONT BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Estimated, originating in			
Directly tributary mountains	1,940	1,550	1,530
Directly tributary hills	4,160	4,200	4,120
Total [a]	6,100	5,750	5,650

[a] Includes a relatively large but undetermined amount of underflow.

Consumptive Use

In Table 155 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. The City of Beaumont is the only municipal development. Because of the altitude, deciduous orchards constitute the principal irrigated crop. Cover on unirrigated lands ranges from heavy brush and small trees at higher levels, to grass and weeds where the altitude is less.

TABLE 155. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN BEAUMONT BASIN

Type of culture	*Unit consumptive use, feet*	*1932 Acres*	*1932 Acre-feet*	*1942 Acres*	*1942 Acre-feet*
Valley and folded area					
Garden and field	1.4	86	120	176	246
Deciduous	2.3	2,579	5,932	2,384	5,483
Alfalfa	3.0	3	9	18	54
Irrigated grass	3.0	0	0	5	15
Domestic and industrial	1.8	519	934	599	1,078
Unirrigated	----	16,472	----	16,477	----
32-year period	1.6	----	----	----	26,363
21-year period	1.606	----	----	----	26,462
11-year period	1.594	----	26,256	----	----
Subtotal	----	19,659	----	19,659	----
32-year period	----	----	----	----	33,239
21-year period	----	----	----	----	33,338
11-year period	----	----	33,251	----	----
Hill area					
Deciduous	0.9 [a]	41	37	41	37
Grand total	----	19,700	----	19,700	----
32-year period	----	----	----	----	33,276
21-year period	----	----	----	----	33,375
11-year period	----	----	33,288	----	----

[a] Difference between irrigated culture and natural vegetation.

† If inflow from hills is assumed to follow the same regimen of flow as the Santa Ana River, estimated annual inflow is 3,330 and 3,290 acre-feet during the 21- and 11-year periods, respectively.

Historical Export

In Table 156 estimated exports of water from pumped sources to San Timoteo Basin for each year since 1927-28 are presented. There is no sewage outflow. During the 11-year period an annual average of 2,620 acre-feet was exported.

TABLE 156. EXPORT FROM BEAUMONT BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	3,370	1933-34	2,680	1939-40	2,050
1928-29	3,520	1934-35	2,120	1940-41	1,820
1929-30	2,810	1935-36	2,250	1941-42	2,340
1930-31	2,950	1936-37	1,810	1942-43	2,270
1931-32	2,550	1937-38	1,990	1943-44	2,090
1932-33	2,740	1938-39	2,180	1944-45	1,740

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and hills, and runoff originating in precipitation on the overlying valley. It is estimated to average 1,090 acre-feet, 1,070 acre-feet and 1,040 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 157.

The area of mountains directly tributary to the basin is not large, and geological investigations indicate that a considerable part of the estimated mountain inflow enters the valley as underflow. The remainder flows, principally in unpaved channels of Little San Gorgonio and Noble Creeks, a distance of 10 miles or more southward across the alluvium to San Timoteo Creek, near the south boundary of the basin. Tributary hills are also for the most part some distance from the boundary. It is estimated that outflow from this basin includes 10 percent of inflow from directly tributary mountains and hills, 5 percent of precipitation on 2,390 acres of land classified as folded, and 1 percent of precipitation on valley land within the basin.

TABLE 157. SURFACE OUTFLOW FROM BEAUMONT BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Estimated, originating in			
Directly tributary mountains	190	160	150
Directly tributary hills	420	420	410
Precipitation on valley and folded land	480	490	480
Total	1,090	1,070	1,040

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period must, in accordance with principles set forth in Chapter V, have averaged 3,800 acre-feet annually, as derived in Table 158.

TABLE 158. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM BEAUMONT BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	34,360	
Surface inflow	5,650	
Water coming from storage in basin	740	
Subtotal		40,750
Water leaving basin on surface		
Surface outflow	1,040	
Export	2,620	
Consumptive use	33,290	
Subtotal		36,950
SUBSURFACE OUTFLOW—to San Timoteo Basin		3,800

Long-time Mean Amount Available for Export

The hydrologic equation used in the foregoing article applies equally well in any period. Since there is considered to be neither excess nor overdraft, net change in storage over a cycle of long-time mean supply is zero. Assuming that subsurface outflow is the same in all periods, all items involved except export have been evaluated for both 32- and 21-year cycles. Assuming that the 21-year period is the cycle of long-time mean supply and that the independently derived values are all correct, estimated long-time mean annual amount available for export is 2,420 acre-feet, as derived in Table 159. If 32-year mean annual values are substituted, the value derived is 2,550 acre-feet.

TABLE 159. ESTIMATED AVERAGE ANNUAL AMOUNT AVAILABLE FOR EXPORT FROM BEAUMONT BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	
Supply to basin		
Precipitation	34,920	
Surface inflow	5,750	
Subtotal		40,670
Demand on basin, excluding export		
Consumptive use	33,380	
Surface outflow	1,070	
Subsurface outflow	3,800	
Subtotal		38,250
AVAILABLE FOR EXPORT		2,420

However, throughout the greater portion of the basin, including the area near index well E-233f, no net rise in ground water level has occurred during the period 1936-37 to date, even though precipitation has averaged 23 percent greater than the long-time mean and export averaged only a little more than 2,000 acre-feet per year. This indicates that the value of export which results in no overdraft, i.e. no drop in ground water level during a period of mean supply must be less than 2,000 acre-feet.

Assuming that Wells E-233f, E-240 and E-245, shown on Plate 20, are index wells for the basin as a whole, each foot change in water table elevation at the first represents 900 acre-feet, and at each of the others represents 600 acre-feet change in storage in the basin. If this assumption is correct, a reduction of export from an average of 2,480 acre-feet to between 1,500 and 1,600 acre-feet should have resulted in no net drop in water table elevation at the three wells during the 15-year period, 1927-28 to 1941-42, inclusive, in which precipitation averaged only 6 percent greater than the mean.

From inspection of Table 159 it is apparent that relatively small errors in the estimated values of precipitation and consumptive use might result in considerable error in the value of export derived by the procedure shown there. On the other hand, the assumption that the drop which has occurred at the above three wells was as great over the entire basin is open to question. Until such time as experience provides a more dependable answer, permissible export from this basin, with conditions otherwise those of the present, is estimated to average 1,800 acre-feet annually.

SAN TIMOTEO BASIN (26)

San Timoteo Basin is located in the south central portion of Upper Santa Ana Valley, and covers about 45 square miles. It is bounded on the south by Reche Canyon Basin and the watershed of San Jacinto River, on the north by Bunker Hill Basin, and on the northeast and east by Yucaipa and Beaumont Basins. The folded formation which makes up a very large part of this basin results in broken, irregular topography. The slope, in the northwesterly direction of flow of San Timoteo Creek, is about 100 feet per mile. Elevations above sea level range from 1,075 to 2,400 feet. Soils covering the larger, folded portion of this basin are of the Placentia series. Narrow bottom lands along San Timoteo Creek are covered with more pervious Hanford sands and sandy loams. Municipal development occupies only about 2 percent of the area, about 20 percent is devoted to agriculture, and the remainder is largely in a natural state.

The local water supply, utilized to a minor extent through diversion from surface streams and through pumping from ground water, originates in precipitation on the valley, inflow from 2,130 acres of hills directly tributary to the basin, and inflow both underground and on the surface from Beaumont and Yucaipa Basins. Imported water provides a large part of the supply.

A considerable part of the surface inflow and precipitation flows out into Bunker Hill Basin, together with large underflow, and water is exported in relatively large amount to San Jacinto River Valley.

Since there is no effective barrier to underflow into Bunker Hill Basin, any apparent excess or deficiency in supply resulting from changes in the relatively small extractions or large imports is soon compensated for by a corresponding increase or decrease in subsurface outflow. Therefore, neither excess nor overdraft is considered to exist, and long-time mean subsurface outflow under present condition is the value estimated herein. Evaluation of items required * to estimate its amount follows.

Inflow

Estimated annual surface inflow averages 2,280 acre-feet, 2,210 acre-feet and 2,170 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 160.

The estimate of inflow from 2,130 acres of directly tributary hills is based on the assumption that 9 percent of precipitation thereon runs off.† Inflow on the surface from other basins includes all surface outflow from Beaumont Basin, and a large part of that from Yucaipa Basin. Subsurface inflow includes the underflow out of Yucaipa and Beaumont Basins. During the 11-year period this averaged 2,920 and 3,800 acre-feet annually from the respective basins, a total of 6,720 acre-feet.

TABLE 160. SURFACE INFLOW TO SAN TIMOTEO BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
From directly tributary hills			
Estimated [a]	250	260	260
From other basins			
Yucaipa	940	880	870
Beaumont	1,090	1,070	1,040
Total [a]	2,280	2,210	2,170

[a] Includes a relatively small amount of underflow.

Import

In Table 161 estimated imports of water for each year since 1927-28 are presented. There is no import of sewage. Water is imported for use from both gravity and pumped sources in Bunker Hill, Yucaipa, and Beaumont Basins. During the 11-year period an annual average of 20,300 acre-feet was imported.

The amount of water imported depends to some extent upon the amount of gravity water available. Present average annual import from Santa Ana River for export to San Jacinto Valley, which is based on ownership of Bear Valley Mutual Water Company stock, is assumed to equal the historic average for the 21-year period. Present average annual import for other purposes, partly from the river and partly pumped, is estimated to equal the average for the four-year period, 1941-42 to 1944-45, inclusive. Total present average annual import, so estimated, is 18,150 acre-feet.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

† If inflow from hills is assumed to follow the same regimen as flow in Santa Ana River, estimated average annual inflow during the 21- and 11-year periods is 200 acre-feet.

TABLE 161. IMPORT TO SAN TIMOTEO BASIN

Year	Acre-feet	Year	Acre-feet	Year	Acre-feet
1927-28	21,840	1933-34	19,190	1939-40	20,350
1928-29	19,390	1934-35	17,780	1940-41	21,720
1929-30	18,310	1935-36	20,720	1941-42	18,900
1930-31	19,170	1936-37	19,320	1942-43	18,430
1931-32	22,650	1937-38	22,900	1943-44	18,660
1932-33	21,980	1938-39	22,940	1944-45	17,040

Consumptive Use

In Table 162 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. All municipal development, and by far the greater part of irrigated culture lies within or adjacent to the City of Redlands. The rest is scattered along the narrow valley of San Timoteo Creek. Folded lands, almost entirely unirrigated, are for the most part covered with moderately heavy brush.

TABLE 162. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN SAN TIMOTEO BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley and folded area					
Garden and field	1.4	70	98	80	112
Avocado and citrus	2.7	5,011	13,530	5,181	13,989
Deciduous	2.3	261	600	201	462
Alfalfa	3.0	178	534	198	594
Irrigated grass	3.0	62	186	77	231
Domestic and industrial	1.8	630	1,134	695	1,251
Unirrigated	----	22,804	----	22,584	----
32-year period	1.2	----	----	----	27,101
21-year period	1.217	----	----	----	27,485
11-year period	1.210	----	27,593	----	----
Subtotal	----	29,016	----	29,016	----
32-year period	----	----	----	----	43,740
21-year period	----	----	----	----	44,124
11-year period	----	----	43,675	----	----
Hill area					
Garden and field	0.2 [a]	5	1	5	1
Avocado and citrus	1.5 [a]	30	45	30	45
Subtotal	----	35	46	35	46
Grand total	----	29,051	----	29,051	----
32-year period	----	----	----	----	43,786
21-year period	----	----	----	----	44,170
11-year period	----	----	43,721	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 163 estimated exports of water from both gravity and pumped sources to San Jacinto Valley for each year since 1927-28 are presented. There is no sewage outflow. During the 11-year period an annual average of 3,800 acre-feet was exported. Present average annual export of gravity water is assumed to equal its historic average for the 21-year period, that of pumped water to equal its average for the four-year period, 1941-42 to 1944-45, inclusive. The total is 3,610 acre-feet.

TABLE 163. EXPORT FROM SAN TIMOTEO BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	4,970	1933-34	3,740	1939-40	3,530
1928-29	4,400	1934-35	2,940	1940-41	3,090
1929-30	3,690	1935-36	3,590	1941-42	3,930
1930-31	4,280	1936-37	3,020	1942-43	3,730
1931-32	4,060	1937-38	3,520	1943-44	3,770
1932-33	3,640	1938-39	3,840	1944-45	3,450

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary hills, a part of that from Yucaipa and Beaumont Basins and runoff originating in precipitation on the overlying valley. It is estimated to average 2,230 acre-feet, 2,080 acre-feet and 1,740 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 164.

Inflow from a little more than half of 2,130 acres of hill land directly tributary to this basin flows westward for about five miles across recent alluvium in the northerly portion of the basin. Inflow from the remainder flows northward across about two miles of older folded formation into the narrow bottom lands of San Timoteo Creek, after which it traverses about two miles of recent alluvium bordering that stream. Discharge of San Timoteo Creek has been measured at Stations 18096 and 18128 since 1926-27. Unpublished data from the United States Geological Survey are available, from which estimates of outflow in that stream during prior years have been made. Estimated outflow originating below the gaging stations includes 90 percent of the inflow from directly tributary hills, 5 percent of the precipitation on the folded area, and 1 percent of the precipitation on valley area within the basin.

TABLE 164. SURFACE OUTFLOW FROM SAN TIMOTEO BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Measured during part of period	1,720	1,540	1,200
Estimated, originating in			
Directly tributary hills	120	130	130
Precipitation on valley and folded lands	390	410	410
Total	2,230	2,080	1,740

Subsurface Outflow

In accordance with principles set forth in Chapter V, historic average annual subsurface outflow during the 11-year period, and present long-time mean annual subsurface outflow under two assumptions as to cycle of long-time mean supply, are derived in Table 165. The difference between 32- and 21-year values is due primarily to difference in estimated precipitation for the two periods. Since mean precipitation for the 53-year period is less than the average during either 32- or 21-year cycles, annual subsurface outflow is estimated to be 13,960 acre-feet, this being the more conservative value.

TABLE 165. ESTIMATED SUBSURFACE OUTFLOW FROM SAN TIMOTEO BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Water entering basin			
Precipitation	36,440	37,490	37,030
Surface inflow	2,280	2,210	2,170
Subsurface inflow	6,720	6,720	6,720
Import	18,150	18,150	20,300
Subtotal	63,590	64,570	66,220
Increase in storage	0	0	230
Water leaving basin on surface			
Consumptive use	43,790	44,170	43,720
Surface outflow	2,230	2,080	1,740
Export	3,610	3,610	3,800
Subtotal	49,630	49,860	49,490
SUBSURFACE OUTFLOW—to Bunker Hill Basin	13,960	14,710	16,730

BUNKER HILL BASIN (22)

Bunker Hill Basin is located in the east central portion of Upper Santa Ana Valley, and covers about 92 square miles. It is bounded on the west and southwest by Lytle and Colton Basins, on the northwest by Lower Cajon Basin, on the north and northeast by Devil Canyon Basin and San Bernardino Mountains, and on the south by San Timoteo and Yucaipa Basins and granitic hills northwest of the latter. Topography is the result of deposition and erosion by Cajon Creek entering the valley from the northwest, by Santa Ana River and Mill Creek from the east, and by many smaller streams entering from mountains to the north and hills to the south. Each of the larger streams has formed a well-defined alluvial cone. For several miles out in the valley Mill Creek and Santa Ana River have cut many channels of considerable depth. General slope here ranges from 175 to 400 feet per mile. Along mountains which form the northeast boundary of the basin the slope is also steep, averaging about 250 feet per mile. On the Cajon Creek cone the slope is to the southeast, and averages 125 feet per mile. Where all cones coalesce in the central portion of the basin, topography is regular, with an average slope of 50 feet per mile. In the lower portion of the basin topography is again irregular. Elevations range from 960 feet where Warm Creek flows out of the basin, to 1,860 feet where Cajon Creek enters, and to about 2,500 feet at the easterly extremity where Mill Creek enters the valley. Soils covering this basin are mostly lighter members of the Hanford and Tujunga series. In the vicinity of San Bernardino there are considerable areas of the less pervious Chino soils. Municipal development occupies about 19 percent of the area, about 36 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized both through diversion from surface streams and pumping from ground water, originates in precipitation on valley lands, inflow from 272 square miles of mountains and 2,100 acres of hills directly tributary to the basin, and inflow on the surface from Yucaipa, Lytle, Lower Cajon, Devil Canyon and San Timoteo Basins, together with some underflow from the four last named. Imported water provides some addition to the supply.

A considerable part of surface inflow and precipitation flows out into Colton Basin, together with some underflow, and water is exported in large amount to Colton and San Timoteo Basins.

Like Main San Gabriel Basin, Bunker Hill Basin is one in which outflow of rising water responds quickly to changes in elevation of the water table, and it is therefore considered that neither excess nor overdraft exists, but that the basin serves as a regulator of outflow to basins downstream. Evaluation of items required * to estimate long-time mean outflow follows.

Inflow

Estimated surface inflow to the basin averages 138,370 acre-feet, 114,670 acre-feet and 113,510 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 166.

Annual inflow from directly tributary mountain area, above gaging stations at which flow was measured during part of the period, is tabulated below. Thirty-two- and 21-year values for Mill and City Creeks, and 32-year value for Plunge Creek are derived by comparison with Santa Ana River.

		Mean annual inflow[a] in acre-feet		
Stream	*Station*	*32-year period*	*21-year period*	*11-year period*
Mill Creek	18261	32,320	26,020	26,960
City Creek	18915A	10,130	8,080	7,120
Plunge Creek	18957	6,900	5,540	5,750
Santa Ana River	19008	75,100 [b]	60,340 [b]	55,720 [c]
Subtotal		124,450	99,980	95,550
Estimated evaporation loss from Bear Valley Reservoir		2,350	2,080	----
Net inflow		122,100	97,900	95,550

[a] Including diversions above gaging stations.
[b] Full natural runoff, as reconstructed, corrected for effect of reservoir.
[c] Actual measured runoff, uncorrected for reservoir operation.

The estimate of 32-year mean annual inflow from 12,160 acres of mountains directly tributary to the basin, and downstream from gaging stations at which above inflow was measured is based on the assumption that, if water is available, average consumptive use on the mountain area ranges from 18 to 19 inches, inflow values however being never less than 10 percent of the precipitation. The 11-year value is estimated to be 0.79

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

times the 32-year mean, this being the ratio between 11- and 32-year mean discharge of Santa Ana River. The corresponding ratio for the 21-year period is 0.80. Inflow from 2,100 acres of directly tributary hills is estimated to be 10 percent of the precipitation.* Inflow on the surface from other basins includes all surface outflow from Devil Canyon, San Timoteo and Lytle Basins, and a part of that from Lower Cajon and Yucaipa Basins.

Subsurface inflow includes underflow out of Lower Cajon, Devil Canyon, San Timoteo and Lytle Basins, and is estimated to average 35,200 acre-feet, 31,790 acre-feet and 34,420 acre-feet annually during the 32-, 21- and 11-year periods, respectively.

TABLE 166. INFLOW TO BUNKER HILL BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Surface inflow			
From directly tributary mountains			
Measured during part of period	122,100	97,900	95,550
Estimated [a]	2,790	2,230	2,200
From directly tributary hills			
Estimated [a]	340	340	330
From other basins			
Lower Cajon	2,970	3,530	3,590
Devil Canyon	5,200	4,100	4,250
San Timoteo	2,230	2,080	1,740
Yucaipa	530	430	420
Lytle	2,210	4,060	5,430
Total surface inflow [a]	138,370	114,670	113,510
Subsurface inflow from other basins			
Lower Cajon	13,590	11,330	13,150
Devil Canyon	7,060	5,160	3,950
San Timoteo	13,960	14,710	16,730
Lytle	590	590	590
Total subsurface inflow	35,200	31,790	34,420

[a] Includes a relatively small amount of underflow.

Import

In Table 167 estimated values of imports of water from Lytle, Devil Canyon and Lower Cajon Basin for each year since 1927-28 are presented. There is no import of sewage. During the 11-year period an annual average of 3,580 acre-feet was imported.

Assuming that the import from Lower Cajon Basin in 1943-44 and the four-year average import from Lytle and Devil Canyon Basins during 1941-42 to 1944-45, inclusive, represent present average annual import, its estimated value is 8,490 acre-feet.

* If inflow from hills is assumed to follow the same regimen as flow in Santa Ana River, average inflow from that source is 270 acre-feet for both 21- and 11-year periods.

TABLE 167. IMPORT TO BUNKER HILL BASIN

Year	Acre-feet	Year	Acre-feet	Year	Acre-feet
1927-28	3,820	1933-34	3,160	1939-40	4,650
1928-29	3,460	1934-35	2,990	1940-41	6,100
1929-30	3,780	1935-36	3,270	1941-42	6,650
1930-31	3,260	1936-37	4,130	1942-43	8,200
1931-32	3,470	1937-38	4,280	1943-44	8,980
1932-33	3,720	1938-39	5,080	1944-45	9,180

Consumptive Use

In Table 168 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. The greater part of the Cities of San Bernardino and Redlands overlie the basin. The principal agricultural crop, citrus, covers a large part of the area south of Santa Ana River, and that bordering the mountains on the north. Smaller acreages of other crops occupy level lands near San Bernardino. Moderately heavy brush, weeds and grass cover most of the unirrigated area.

TABLE 168. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN BUNKER HILL BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley and folded area					
Garden and field	1.4	2,722	3,811	2,692	3,769
Avocado and citrus	2.7	16,095	43,456	16,230	43,821
Deciduous	2.3	546	1,256	261	600
Alfalfa	3.0	1,014	3,042	929	2,787
Irrigated grass [a]	4.0	1,126 [a]	4,504	1,391 [a]	5,564
Domestic and industrial	1.8	9,503	17,105	10,943	19,697
Unirrigated	----	27,830	----	26,390	----
32-year period	1.3	----	----	----	34,307
21-year period	1.305	----	----	----	34,439
11-year period	1.295	----	36,040	----	----
Subtotal	----	58,836	----	58,836	----
32-year period	----	----	----	----	110,545
21-year period	----	----	----	----	110,677
11-year period	----	----	109,214	----	110,677
Hill and mountain area					
Avocado and citrus	1.2 [b]	130	156	130	156
Grand total	----	58,966	----	58,966	----
32-year period	----	----	----	----	110,701
21-year period	----	----	----	----	110,833
11-year period	----	----	109,370	----	----

[a] Includes water-loving natural vegetation in pressure zone above Bunker Hill Dike.
[b] Difference between irrigated culture and natural vegetation.

Export

In Table 169 estimated exports of water to Colton and San Timoteo Basins and of sewage to Colton Basin for each year since 1927-28 are presented. Exports include both pumped water and gravity water diverted within the basin. During the 11-year period an annual average of 67,500 acre-feet of water and 3,040 acre-feet of sewage was exported, a total of 70,540 acre-feet.

Estimated average annual export of water under present conditions is 66,390 acre-feet, and of sewage 6,780 acre-feet, a total of 73,170 acre-feet. Present average annual export of gravity water to San Timoteo Basin is assumed to equal the historic average during the 21-year period. Average export of other water during 1941-42 to 1944-45, inclusive, and of sewage in 1944-45 alone, are assumed to represent the average from those sources under present conditions.

TABLE 169. EXPORT FROM BUNKER HILL BASIN

(Acre-feet)

Year	Water	Sewage	Year	Water	Sewage
1927-28	62,540	0	1936-37	62,510	3,550
1928-29	65,800	2,470	1937-38	68,680	3,230
1929-30	63,320	3,490	1938-39	71,090	3,750
1930-31	70,210	3,290	1939-40	71,970	3,480
1931-32	67,570	3,200	1940-41	63,540	3,840
1932-33	71,880	2,980	1941-42	68,660	4,140
1933-34	73,610	3,920	1942-43	66,250	4,720
1934-35	60,440	4,110	1943-44	64,490	5,590
1935-36	75,900	3,150	1944-45	66,600	6,780

Surface Outflow During 11-Year Period

During the 11-year period more than half the surface outflow, that in Warm Creek, was measured at Station 17993A. Flow in Santa Ana River was measured at Station 17993B in 1927-28, at Station 18041 from 1928-29 to 1936-37, inclusive, and at Station 18003 from March 1939 to date. Station 18041 is above the junction with San Timoteo Creek, so small outflow originating in that source, estimated by entering the percolation diagram with measured discharges at Stations 18096 and 18128, is added. Outflow in Santa Ana River in 1937-38 is estimated by comparison with flow in the river at Prado, Station 15822. Outflow in the West Branch of Lytle Creek has been measured at Station 17982 since January, 1929. Runoff for 1927-28 and the first three months of 1928-29 was negligible. Relatively small outflow to Lytle Basin in Cajon Creek is estimated throughout by use of the percolation diagram and measured daily discharges at Stations 19433A and 19433B, modified to include estimated inflow below the stations. Estimated outflow during the 11-year period averages 38,190 acre-feet, of which 35,550 acre-feet goes to Colton Basin and 2,640 acre-feet to Lytle Basin, as derived in Table 170.

TABLE 170. AVERAGE ANNUAL SURFACE OUTFLOW[a] FROM BUNKER HILL BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
To Colton Basin		
Measured, in Warm Creek	22,150[b]	
Partially estimated		
In Santa Ana River	12,850	
In West Branch of Lytle Creek	550	
Subtotal		35,550
To Lytle Basin		
Estimated, in Cajon Creek	2,640	
Total		38,190

[a] Does not include outflow in canals which divert gravity water within the basin for export.
[b] Does not include effluent from City of San Bernardino sewage treatment plant.

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year period must, in accordance with principles set forth in Chapter V, have averaged 20,110 acre-feet annually, as derived in Table 171.

TABLE 171. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM BUNKER HILL BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	86,180	
Surface inflow	113,510	
Import	3,580	
Subsurface inflow	34,420	
Water coming from storage in basin	520	
Subtotal		238,210
Water leaving basin on surface		
Surface outflow	38,190	
Exported water	67,500	
Exported sewage	3,040	
Consumptive use	109,370	
Subtotal		218,100
SUBSURFACE OUTFLOW—to Colton-Reche Canyon Area		20,110

Long-time Mean Surface Outflow

The hydrologic equation used in the preceding article applies equally well in any period. Since neither excess nor overdraft is considered to exist, net change in storage over a cycle of long-time mean supply is zero. Assuming that subsurface outflow is the same in all periods, all items involved, other than surface outflow, have been evaluated for both 32- and and 21-year cycles. Assuming further that the 21-year period represents the cycle of long-time mean supply, estimated mean annual surface outflow is 38,440 acre-feet, as derived in Table 172. If the 32-year period were assumed to be the cycle, the derived value would be 64,930 acre-feet.

Outflow in Cajon Creek to Lytle Basin for each year since 1920-21 is estimated by means of percolation curves which result in complete percolation up to 85 second-feet in Lower Cajon Basin and 100 second-feet in Bunker Hill Basin, and daily discharges in Lone Pine and Cajon Creeks at Stations 19433A and 19433B, respectively. Runoff in Lone Pine Creek was measured from 1920-21 to 1937-38, inclusive, and that in Cajon Creek from 1920-21 to date. Daily discharges in Lone Pine Creek after 1937-38 are estimated by comparison with Cajon Creek. Estimated daily discharges in Cajon Creek at Lower Cajon Basin boundary are increased by 45 percent to allow for inflow below the gaging stations. Annual combined runoff at the two stations for years prior to 1920-21 is estimated by comparison with San Antonio Creek. Outflow to Lytle Basin in each of these earlier years is estimated from the relationship between outflow and discharge at the stations, established since 1920-21. On this basis, estimated average annual outflow to Lytle Basin for the 32-year period is 1,570 acre-feet, and for the 21-year period, 2,490 acre-feet.

Outflow in Santa Ana River during the 11-year period has been previously discussed. It has been measured at Station 18003 since March 1939. Outflow for years prior to 1927-28 and for 1938-39 is estimated from relationship of outflow to 32-year mean runoff indices for Santa Ana River, as established by years of record. On this basis, estimated mean annual outflow in Santa Ana River for the 32-year period is about 21,000 acre-feet, and for the 21-year period, 14,000 acre-feet, nearly all of which is storm water.

Deducting estimated outflow in Cajon Creek and Santa Ana River from calculated total mean outflow from the basin, leaves approximately 42,000 acre-feet mean annual outflow in Warm Creek for the 32-year period, and 22,000 acre-feet for the 21-year period. Most of the outflow in Warm Creek is rising water.

TABLE 172. ESTIMATED LONG-TIME MEAN ANNUAL SURFACE OUTFLOW FROM BUNKER HILL BASIN ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE A CYCLE OF LONG-TIME MEAN SUPPLY

	Acre-feet	
Supply to basin		
Precipitation	87,600	
Surface inflow	114,670	
Import	8,490	
Subsurface inflow	31,790	
Subtotal		242,550
Demand on basin		
Consumptive use	110,830	
Export	73,170	
Subsurface outflow	20,110	
Subtotal		204,110
SURFACE OUTFLOW		38,440
To Lytle Basin		2,490
To Colton-Reche Canyon Area:		
In Santa Ana River		14,000
In Warm Creek		21,950

COLTON-RECHE CANYON AREA

Colton Basin (21b)
Reche Canyon Basin (45)

There is no physical barrier to movement of ground water between Reche Canyon and Colton Basins. Since development in the former basin is limited to dry-farming it is obvious that it has no overdraft, and since no changes have occurred which would tend to decrease outflow, and thus increase supply, it has no excess. Because of this the two basins are treated as a unit, Reche Canyon being considered an arm of Colton Basin and a source of supply to it.

The area is located in the south central portion of Upper Santa Ana Valley, and covers about 19 square miles. Colton Basin is bounded on the southwest by Riverside Basin, on the west and northwest by Rialto Basin, and on the northeast and east by Lytle and Bunker Hill Basins. Reche Canyon Basin extends southeasterly from Colton Basin, and is bounded on the west and south by the granitic hills which border Riverside Basin and San Jacinto Valley, and on the north and east by San Timoteo Basin. Topography of Colton Basin is somewhat rolling and irregular because of sand dune formations which cover a considerable part of its lower portion. Average slope is less than 100 feet per mile, and elevations range from 925 feet along Santa Ana River to 1,425 feet at the most northerly point in the basin. The surface overlying Reche Canyon Basin is steep and irregular, ranging in elevation above sea level from 1,025 feet at Colton Basin boundary, to 2,100 feet along the toe of hills to the southeast. The soils are mostly lighter members of the Hanford and Tujunga series, with however a considerable area of windblown Oakley sand in Colton Basin, and some residual Sierra loam in Reche Canyon Basin.

The local water supply, utilized in part through diversion from surface streams and in part through pumping from ground water, originates in precipitation on valley land, inflow from 3,630 acres of hills directly tributary to the area, and inflow both underground and on the surface from Bunker Hill Basin, the greater part of the last named as flood flow and rising water in Santa Ana River and Warm Creek. Imported water, most of which is carried through and exported, provides a relatively large addition to the supply entering the area. Considerable sewage is also imported.

A large part of the surface inflow and precipitation flows out into Riverside Basin, together with underflow, and water is exported in large amount to Riverside, Rialto and Chino Basins. Local sewage is exported to Riverside Basin. A part of the sewage imported from Bunker Hill Basin flows through into Riverside Basin in Santa Ana River. This is considered a part of the flow in that stream rather than export.

Long-time mean annual supply entering the area under present conditions is greater than present annual demand, but storage capacity above present water table is so limited that all unused water soon flows out, constituting a part of the supply to basins downstream. It is the long-time mean outflow to downstream basins under present development which is herein estimated. Evaluation of items required * for the estimate follows.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Inflow

Estimated annual surface inflow averages 63,610 acre-feet, 36,220 acre-feet and 35,810 acre-feet during the 32-, 21- and 11-year periods, respectively, as derived in Table 173. The estimate of inflow from 3,630 acres of hills directly tributary to the area is based on the assumption that 6 percent of precipitation on the hills runs off.

The greater part of the surface outflow and most of the underflow from Bunker Hill Basin is a part of the inflow to the area. Subsurface inflow, with the exception of the relatively small amount referred to by note in Table 173, is all from this source, and during the 11-year period averaged 20,110 acre-feet annually.

TABLE 173. SURFACE INFLOW TO COLTON-RECHE CANYON AREA

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
From directly tributary hills			
Estimated [a]	250	270	260
From other basins			
Bunker Hill	63,360	35,950	35,550
Total	63,610	36,220	35,810

[a] Includes a relatively small amount of underflow.

Import

In Table 174 estimated values of imports of water from both gravity and pumped sources in Rialto, Bunker Hill and Lytle Basins, and of sewage from Bunker Hill Basin, for each year since 1927-28 are presented. During the 11-year period an annual average of 59,780 acre-feet of water, and 3,040 acre-feet of sewage was imported, a total of 62,820 acre-feet.

Estimated average annual import of water under present conditions is 64,180 acre-feet, and of sewage 6,780 acre-feet, a total of 70,960 acre-feet. It is assumed that average annual historic import of water during the four-year period, 1941-42 to 1944-45, inclusive, and the historic import of sewage during 1944-45 represent the respective average annuals under present conditions.

TABLE 174. IMPORT TO COLTON-RECHE CANYON AREA

(Acre-feet)

Year	*Water*	*Sewage*	*Year*	*Water*	*Sewage*
1927-28	56,800	0	1936-37	53,600	3,550
1928-29	63,930	2,470	1937-38	56,620	3,230
1929-30	59,080	3,490	1938-39	61,780	3,750
1930-31	64,460	3,290	1939-40	65,790	3,480
1931-32	55,070	3,200	1940-41	53,580	3,840
1932-33	60,920	2,980	1941-42	64,820	4,140
1933-34	66,700	3,920	1942-43	64,380	4,720
1934-35	52,520	4,110	1943-44	62,410	5,590
1935-36	67,840	3,150	1944-45	65,100	6,780

Consumptive Use

In Table 175 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. A portion of the City of Rialto, and the greater part of the City of Colton, overlie Colton Basin. Citrus covers most of its northerly portion, and relatively smaller areas of other crops occupy lower lands. A part of its unirrigated acreage is devoted to grapes, and the remainder is largely covered by grass and weeds. In Reche Canyon Basin valley lands are largely grass covered or dry farmed, with moderately heavy brush on folded areas.

TABLE 175. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN COLTON-RECHE CANYON AREA

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley and folded area					
Garden and field	1.4	302	423	122	171
Avocado and citrus	2.5	3,622	9,055	3,442	8,605
Deciduous	2.3	137	315	97	223
Alfalfa	3.0	133	399	338	1,014
Irrigated grass	3.0	30	90	50	150
Domestic and industrial	1.8	1,365	2,457	1,480	2,664
Unirrigated	----	6,728	----	6,788	----
32-year period	1.1	----	----	----	7,467
21-year period	1.111	----	----	----	7,541
11-year period	1.103	----	7,421	----	----
Total	----	12,317	----	12,317	----
32-year period	----	----	----	----	20,294
21-year period	----	----	----	----	20,368
11-year period	----	----	20,160	----	----

Export

In Table 176 estimated exports of water and sewage for each year since 1927-28 are presented. Water, both gravity and pumped, is exported to Chino, Rialto and Riverside Basins, while sewage goes to Riverside Basin. During the 11-year period annual averages of 66,620 acre-feet of water, and 470 acre-feet of sewage were exported, a total of 67,090 acre-feet.

Estimated average annual export of water under present conditions is 73,020 acre-feet, and of sewage 890 acre-feet, a total of 73,910 acre-feet. Present average annual exports of water and of sewage are assumed to equal the historic average annual for the four-year period, 1941-42 to 1944-45, inclusive, and the 1944-45 value, respectively.

TABLE 176. EXPORT FROM COLTON-RECHE CANYON AREA

(Acre-feet)

Year	Water [a]	Sewage	Year	Water [a]	Sewage
1927-28	77,740	450	1936-37	56,200	560
1928-29	80,930	470	1937-38	62,960	610
1929-30	68,190	420	1938-39	67,530	660
1930-31	70,370	440	1939-40	70,920	710
1931-32	62,060	440	1940-41	56,440	970
1932-33	64,930	400	1941-42	72,830	670
1933-34	65,840	420	1942-43	71,670	710
1934-35	53,840	480	1943-44	71,140	840
1935-36	69,720	500	1944-45	76,450	890

[a] Includes part of imported sewage.

Outflow

In accordance with the physical law that all water which enters Colton-Reche Canyon Area during any period, including its overlying area, must either go into storage, be consumed or exported, or flow out either on the surface or underground, estimated surface outflow averages 56,270 acre-feet, 29,130 acre-feet and 27,510 acre-feet annually in the 32-, 21- and 11-year periods, respectively, as derived in Table 177. Since the 21-year value is the more conservative, 29,130 acre-feet is considered to be the long-time mean annual surface outflow. Subsurface outflow is arbitrarily assumed to equal subsurface inflow, i.e. 20,110 acre-feet annually.

TABLE 177. ESTIMATED OUTFLOW FROM COLTON-RECHE CANYON AREA

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	21-year period	11-year period
Water entering area			
Precipitation	15,900	16,230	16,000
Surface inflow	63,610	36,220	35,810
Imported water	64,180	64,180	59,780
Imported sewage	6,780	6,780	3,040
Subsurface inflow	20,110	20,110	20,110
Decrease in storage	0	0	130
Subtotal	170,580	143,520	134,870
Water leaving basin other than outflow			
Exported water	73,020	73,020	66,620
Exported sewage	890	890	470
Consumptive use	20,290	20,370	20,160
Subtotal	94,200	94,280	87,250
OUTFLOW—to Riverside Basin	76,380	49,240	47,620
Subsurface	20,110	20,110	20,110
Surface	56,270	29,130	27,510

RIVERSIDE-ARLINGTON AREA

Riverside Basin (27)
Arlington Basin (28)

The boundary between Riverside and Arlington Basins was established to coincide with the ground water divide which existed in 1932. Under other conditions this divide might shift and ground water might then flow across the established boundary from either basin to the other, depending upon direction of water table slope then existing. Both basins receive a large imported supply from Bunker Hill and Colton Basins. For these reasons the two basins are treated as a unit.

The area is located in the south central portion of Upper Santa Ana Valley, and covers about 75 square miles. Granitic hills form the southeast and south boundary, as well as the greater part of that on the southwest, west and northwest. The alluvium, however, is continuous between Arlington and Temescal Basins over a width of a little more than one-half mile, and between Riverside and Chino Basins over a considerably greater distance. Colton Basin bounds Riverside Basin on the northeast. Topography of Riverside-Arlington Area is irregular, with slopes generally toward the river ranging from 10 to 400 feet per mile. In the southwesterly portion of Arlington Basin slope is toward Temescal Basin. Elevations above sea level range from 685 to 1,300 feet. Soils covering the portion of Riverside Basin which lies north of Santa Ana River are mostly lighter members of the Hanford series, with a fairly large area of Oakley sand west of the City of Colton. Adjoining either side of the river a strip ranging from one-half to two miles in width is covered with still more pervious Tujunga sands. South of the river lie extensive areas of Hanford, Ramona and Placentia soils, with the latter predominating. Except for a considerable area of heavy Ramona clay loam lying between the City of Arlington and the river, soils covering Arlington Basin are about equally divided between the Hanford and Placentia series. Placentia soils occur in higher, more steeply sloping areas. Municipal development occupies about 18 percent of the area, about 51 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on valley land, inflow from 44,370 acres of hills directly tributary to the area, inflow both underground and on the surface from Colton Basin, and small surface inflow from Chino Basin. The greater part of surface inflow is flood flow and rising water in Santa Ana River. Imported water, together with some sewage, provides a large addition to the supply.

A considerable part of surface inflow and precipitation flows out into Chino and Temescal Basins, together with rising water and underflow. The export of water to these two basins is also considerable.

The water table over most of the area stands higher than the Santa Ana River bed at Riverside Narrows, and there is at all times a large flow of rising water at that point, the amount of which is dependent upon the amount of water used in the basin. So long as this condition exists there is considered to be neither excess nor overdraft, and it is the long-time mean surface outflow which is herein estimated. Evaluation of items required * to estimate its amount follows.

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

Inflow

Estimated annual surface inflow averages 58,450 acre-feet, 31,420 acre-feet and 29,770 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 178.

Estimates of inflow from 44,370 acres of hills directly tributary to the area are based on the assumption that five per cent of precipitation on the hills runs off.* All surface outflow from Colton-Reche Canyon Area, and a small part of that from Chino Basin enters Riverside-Arlington Area. Subsurface inflow, from Colton-Reche Canyon Area, is estimated to average 20,110 acre-feet annually.

TABLE 178. SURFACE INFLOW TO RIVERSIDE-ARLINGTON AREA

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
From directly tributary hills			
Estimated [a]	1,940	2,040	2,020
From other basins			
Colton-Reche Canyon Area	56,270	29,130	27,510
Chino	240	250	240
Total	58,450	31,420	29,770

[a] Includes a relatively small amount of underflow.

Import

In Table 179 estimated values of imports of water and sewage for each year since 1927-28 are presented. Water is imported from Chino and Colton Basins, while sewage inflow is from Colton Basin. Imported water all originates in Colton Basin, and is from both gravity and pumped sources there. During the 11-year period, an annual average of 64,860 acre-feet of water, and 470 acre-feet of sewage were imported, a total of 65,330 acre-feet.

Estimated average annual import of water under present conditions is 70,610 acre-feet, and of sewage 890 acre-feet, a total of 71,500 acre-feet. It is assumed that the historic import for the four-year period, 1941-42 to 1944-45, inclusive, and that for the year 1944-45 alone, determine the present average annual values for water and sewage respectively.

TABLE 179. IMPORT TO RIVERSIDE-ARLINGTON AREA

(Acre-feet)

Year	*Water*	*Sewage*	*Year*	*Water*	*Sewage*
1927-28	76,460	450	1936-37	54,210	560
1928-29	79,530	470	1937-38	60,850	610
1929-30	66,590	420	1938-39	65,700	660
1930-31	68,790	440	1939-40	68,890	710
1931-32	60,310	440	1940-41	54,700	970
1932-33	62,480	400	1941-42	70,890	670
1933-34	64,020	420	1942-43	69,160	710
1934-35	52,560	480	1943-44	68,600	840
1935-36	67,670	500	1944-45	73,790	890

* If inflow from hills is assumed to follow the same regimen as flow in Santa Ana River, estimated average annual inflow from that source during the 21-year period is 1,550 acre-feet, and during the 11-year period, 1,530 acre-feet.

Consumptive Use

In Table 180 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. The Cities of Riverside and Arlington lie within the area. The greater part of the extensive citrus acreage is on northwesterly sloping higher ground, south of the trough of the valley. Other crops dominate lower lands. Natural vegetation, which covers nearly one-third of the area, is largely grass and weeds. Water-loving vegetation, covering areas where the water table is at or near the surface, is classified as irrigated grass. The rate of consumption assigned to this vegetation and to alfalfa grown under similar conditions is higher than that used elsewhere.

TABLE 180. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN RIVERSIDE-ARLINGTON AREA

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley area					
Garden and field	1.4	3,602	5,043	4,070	5,698
Avocado and citrus	2.6	14,339	37,281	14,164	36,826
Deciduous	2.3	2,665	6,130	2,130	4,899
Alfalfa	3.8	2,131	8,098	2,258	8,580
Irrigated grass [a]	3.8	1,660	6,308	2,195	8,341
Domestic and industrial	1.8	8,261	14,870	8,516	15,329
Unirrigated	----	15,519	----	14,844	----
32-year period	0.9	----	----	----	13,360
21-year period	0.922	----	----	----	13,686
11-year period	0.918	----	14,246	----	----
Subtotal	----	48,177	----	48,177	----
32-year period	----	----	----	----	93,033
21-year period	----	----	----	----	93,359
11-year period	----	----	91,976	----	----
Hill area					
Garden and field	0.5 [b]	194	97	209	104
Avocado and citrus	1.7 [b]	1,903	3,235	1,923	3,269
Deciduous	1.5 [b]	184	276	179	268
Alfalfa	2.9 [b]	80	232	80	232
Domestic and industrial	1.0 [b]	1,143	1,143	1,283	1,283
Subtotal	----	3,504	4,983	3,674	5,156
Grand total	----	51,681	----	51,851	----
32-year period	----	----	----	----	98,189
21-year period	----	----	----	----	98,515
11-year period	----	----	96,959	----	----

[a] Includes natural water-loving vegetation.
[b] Difference between irrigated culture and natural vegetation.

Export

In Table 181 estimated exports to Chino and Temescal Basins of combined gravity and pumped water for each year since 1927-28 are presented. There is no sewage outflow. During the 11-year period an annual average of 12,760 acre-feet was exported. Estimated average annual export under present conditions is 10,790 acre-feet, the historic average for the four-year period, 1941-42 to 1944-45, inclusive.

TABLE 181. EXPORT FROM RIVERSIDE-ARLINGTON AREA

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	13,260	1933-34	15,400	1939-40	11,210
1928-29	15,180	1934-35	12,080	1940-41	7,910[a]
1929-30	13,530	1935-36	15,480	1941-42	9,230
1930-31	13,910	1936-37	9,050	1942-43	10,830
1931-32	11,360	1937-38	8,520	1943-44	11,060
1932-33	12,610	1938-39	8,170	1944-45	12,030

[a] Includes a small export to San Jacinto Valley.

Surface Outflow During 11-Year Period

Estimated surface outflow during the 11-year period averages 50,100 acre-feet annually, 47,970 acre-feet of it to Chino Basin and 2,130 acre-feet to Temescal Basin, as derived in Table 182. Discharge of Santa Ana River at Riverside Narrows was measured at Station 16933 in 1927-28, and at Station 16953 after January 8, 1929, except for about four and one-half months in 1937-38. Runoff during periods of no record in 1928-29 and 1937-38 is estimated by comparison with discharge of the river at Station 15822, near Prado. The estimate of rising water outflow in Arlington Drain is based on intermittent measurements since 1941-42 at Station 15991. Estimated unmeasured outflow from the area includes 75 percent of inflow from 8,510 acres and 50 percent of that from 17,100 acres of directly tributary hills, and 5 percent of precipitation on 16,880 acres of valley land.

TABLE 182. AVERAGE ANNUAL SURFACE OUTFLOW FROM RIVERSIDE-ARLINGTON AREA DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Measured during part of period		
Santa Ana River at Riverside Narrows	47,170	
Estimated, originating in		
Rising water in Arlington Drain	1,500	
Directly tributary hills	640	
Precipitation on valley land	790	
SURFACE OUTFLOW		50,100
To Chino Basin, at Riverside Narrows	47,170	
To Chino Basin, near Arlington	800	
Total to Chino Basin		47,970
To Temescal Basin		2,130

Subsurface Outflow During the 11-Year Period

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year period must, in accordance with principles set forth in Chapter V, have averaged 8,550 acre-feet annually, as derived in Table 183. Based on cross sections of the alluvium at River-

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side Narrows and at Temescal Basin boundary, underflow at the two points is estimated independently. The remainder enters Chino Basin above Riverside Narrows.

TABLE 183. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM RIVERSIDE-ARLINGTON AREA DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering area		
Precipitation	49,400	
Surface inflow	29,770	
Import	65,330	
Subsurface inflow	20,110	
Decrease in storage	3,760	
Subtotal		168,370
Water leaving basin on surface		
Surface outflow, to Chino Basin	47,970	
Surface outflow, to Temescal Basin	2,130	
Export	12,760	
Consumptive use	96,960	
Subtotal		159,820
SUBSURFACE OUTFLOW		8,550
To Temescal Basin	3,000	
To Chino Basin, at Riverside Narrows	500	
Subtotal		3,500
To Chino Basin, above Riverside Narrows		5,050

Long-time Mean Outflow

The hydrologic equation expressed in the foregoing article applies equally well in any period. Since it is considered that neither excess nor overdraft exists, net change in storage over a cycle of long-time mean supply is zero. Assuming that subsurface inflow from Colton Basin is the same in all periods, all items involved, other than outflow, have been evaluated for both 32- and 21-year cycles. If the 21-year period is assumed to represent the cycle of long-time mean supply, estimated long-time mean annual outflow is 63,580 acre-feet, as derived in Table 184. Assuming that the percentage of precipitation on valley land, and of inflow from tributary hills which flows out, is the same as for the 11-year period, and that subsurface outflow to Chino and Temescal Basins is the same in all periods, but that lowering of the water table in the lower portion of Arlington Basin results in annual surface outflow to Temescal Basin of only 2,000 acre-feet, resulting surface outflow at Riverside Narrows averages 52,220 acre-feet annually. If the 32-year mean values are substituted, the derived average annual outflow from the area is 88,550 acre-feet, of which 77,230 acre-feet is on the surface at Riverside Narrows.

TABLE 184. ESTIMATED AVERAGE ANNUAL OUTFLOW FROM RIVERSIDE-ARLINGTON AREA ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

	Acre-feet	
Water entering area		
Precipitation	49,860	
Surface inflow	31,420	
Import	71,500	
Subsurface inflow	20,110	
Subtotal		172,890
Water leaving area other than outflow		
Export	10,790	
Consumptive use	98,520	
Subtotal		109,310
OUTFLOW		63,580
Surface, to Temescal Basin	2,000	
Surface, to Chino Basin near Arlington	810	
Subsurface, to Temescal Basin	3,000	
Subsurface, to Chino Basin:		
At Riverside Narrows	500	
Above Riverside Narrows	5,050	
Subtotal		11,360
Surface, to Chino Basin at Riverside Narrows		52,220

TEMESCAL BASIN (29)

Temescal Basin is located in the southerly portion of Upper Santa Ana Valley, and covers about 29 square miles. It is bounded on the southwest and west by Santa Ana Mountains and Santa Ana Narrows Basin, on the north and northwest by Chino Basin and granitic hills, on the northeast by Arlington Basin and granitic hills, and on the east and southeast by granitic hills and Temescal Canyon. Santa Ana River follows the boundary between Temescal and Chino Basins and is assumed to lie just within the latter. Topography is somewhat irregular, though not quite so variable as in other basins lying south of Santa Ana River in Upper Santa Ana Valley. Slope is generally to the north and averages about 200 feet per mile. Elevations range from 475 feet to about 1,500 feet above sea level. Soils are mostly lighter members of the Yolo series, with however a considerable area of Yolo clay loam and Ramona loam, and smaller deposits of heavier Ramona and Chino clay loams. Hanford soils occupy narrow bottom lands along Santa Ana River and Temescal Creek, and Placentia soils cover rougher lands between the two streams. Municipal development occupies about 10 percent of the area, 42 percent is devoted to agriculture, and the remainder is in a more or less natural state.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on valley land, inflow from 9,680 acres of mountains and 11,800 acres of hills directly tributary to the basin, and inflow both underground and on the surface from Arlington Basin and Temescal Canyon, the greater part of the last named as flood flow in Temescal Creek. Imported water provides a large addition to the supply.

A considerable part of the surface inflow and precipitation flows out into Chino Basin, together with large underflow. There is no export of water or sewage at present, although water was exported to Chino Basin from 1929-30 to 1934-35, inclusive.

The greater part of the water herein considered subsurface outflow rises to the surface in the lower portion of the basin and actually crosses the basin boundary on the surface. Slope of the water table toward the river is regular, indicating that there is no physical barrier to movement of ground water toward the river from the area north of the City of Corona where a large part of the extractions occurs. This being true, raising the water table there must result in increase of rising water in the river, or of subsurface outflow from the basin. Raising the water table sufficiently to bring about balance between long-time mean supply, demand and outflow is not considered to constitute excess, and it is the long-time mean subsurface outflow which is herein estimated. Evaluation of items required * for this estimate follows.

Inflow

Estimated annual surface inflow to the basin averages 12,260 acre-feet, 8,690 acre-feet and 7,400 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 185.

Values of inflow from Temescal Canyon for years prior to January, 1928, when measurement at Station 15985 started, are estimated by comparison with Santa Ana River. The estimate of 32-year mean annual inflow from 9,680 acres of mountains directly tributary to the basin, and downstream from Station 15985 ,is based on the assumption that, if water is available, average consumptive use is 19 inches, the inflow however being never less than 10 percent of the precipitation. Average annual inflow from mountains during the 11-year base period is estimated to be 0.79 times the 32-year mean, this being the ratio between 11- and 32-year mean discharge of Santa Ana River. The corresponding ratio for the 21-year period is 0.80. Inflow from 11,800 acres of directly tributary hills is estimated to be 10 percent of the precipitation.†

Subsurface inflow from Arlington Basin is estimated to average 3,000 acre-feet annually.

TABLE 185. SURFACE INFLOW TO TEMESCAL BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Measured during part of period			
From Temescal Canyon, Station 15985	7,400	4,250	2,870
Estimated [a]			
From directly tributary mountains	2,270	1,820	1,790
From directly tributary hills	590	620	610
From other basins			
Arlington	2,000	2,000	2,130
Total	12,260	8,690	7,400

[a] Includes a relatively small amount of underflow.

* Values of change in storage and precipitation are presented in Tables 5 and 7.

† If runoff from hills is assumed to follow the same regimen as flow in Santa Ana River, average annual inflow from that source is 470 acre-feet for both the 21-year and 11-year periods.

Import

In Table 186 estimated values of imports of water for each year since 1927-28 are presented. There is no import of sewage. Water is imported from Riverside-Arlington Area, Temescal Canyon and San Jacinto Valley, and is from both gravity and pumped sources. During the 11-year period, it averaged 14,550 acre-feet annually. Average annual import under present conditions is estimated to equal the historic mean for the four-year period, 1941-42 to 1944-45, inclusive, or 15,420 acre-feet.

TABLE 186. IMPORT TO TEMESCAL BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	15,010	1933-34	14,800	1939-40	14,580
1928-29	15,960	1934-35	12,590	1940-41	11,190
1929-30	16,070	1935-36	17,080	1941-42	15,990
1930-31	14,540	1936-37	13,490	1942-43	14,880
1931-32	12,740	1937-38	14,280	1943-44	15,450
1932-33	13,440	1938-39	14,920	1944-45	15,340

Consumptive Use

In Table 187 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit consumptive use is discussed in Chapter V. The City of Corona is centrally located in the area. Citrus covers the high lands south of the city, while other crops are scattered over lower lands between the city and river. Natural vegetation on unirrigated lands is mostly weeds and light brush.

TABLE 187. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN TEMESCAL BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley area					
Garden and field	1.4	957	1,340	892	1,249
Avocado and citrus	2.5	5,278	13,195	5,598	13,995
Deciduous	2.3	383	881	93	214
Alfalfa	3.0	584	1,752	394	1,182
Irrigated grass	3.0	79	237	659	1,977
Domestic and industrial	1.8	1,413	2,543	1,833	3,299
Unirrigated	----	9,617	----	8,842	----
32-year period	1.1	----	----	----	9,726
21-year period	1.128	----	----	----	9,974
11-year period	1.122	----	10,790	----	----
Subtotal	----	18,311	----	18,311	----
32-year period	----	----	----	----	31,642
21-year period	----	----	----	----	31,890
11-year period	----	----	30,738	----	----
Hill and mountain area					
Garden and field	0.5[a]	571	286	571	286
Avocado and citrus	1.6[a]	99	158	184	294
Deciduous	1.4[a]	419	587	399	559
Alfalfa	2.1[a]	64	134	74	155
Irrigated grass	2.1[a]	202	424	202	424
Domestic and industrial	0.9[a]	484	436	494	445
Subtotal	----	1,839	2,025	1,924	2,163
Grand total	----	20,150	----	20,235	----
32-year period	----	----	----	----	33,805
21-year period	----	----	----	----	34,053
11-year period	----	----	32,763	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 188 estimated values of export to Chino Basin of pumped water for each year of the period, 1929-30 to 1934-35, inclusive, are presented. There was no export prior to the former year and it was stopped in the latter through court action. During the 11-year period an annual average of 1,270 acre-feet of water was exported.

TABLE 188. EXPORT FROM TEMECAL BASIN

Year	Acre-feet	Year	Acre-feet
1929-30	910	1932-33	2,740
1930-31	3,680	1933-34	3,100
1931-32	3,320	1934-35	210

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary mountains and hills, part of that from Arlington Basin and Temescal Canyon, and runoff originating in precipitation on the overlying valley. It is estimated to average 4,600 acre-feet, 3,220 acre-feet and 3,440 acre-feet in the 32-, 21- and 11-year periods, respectivly, as derived in Table 189.

Mean daily discharge of Temescal Creek at Station 15985, near the upper boundary of the basin, has been measured since January, 1928. Using these daily discharges and a percolation curve which results in complete percolation up to 67 second-feet, outflow of water from above the station is estimated for each year since 1927-28. Using the relationship between annual outflow and annual discharge at the station, so established, and discharge at the station in earlier years derived by comparison with Santa Ana River, outflow originating above the gaging station during years prior to 1927-28, is estimated.

The greater part of inflow from directly tributary mountains flows northward across the alluvium an average distance of about four miles into Temescal Wash, and thence an additional distance of two to three miles into Santa Ana River. A smaller area of mountains draining directly to the river lies much closer to the basin boundary. Directly tributary hills border Temescal Creek for a distance of more than five miles. The channel of Temescal Creek is unpaved, with little restriction as to width. Estimated surface outflow from sources other than Temescal Canyon includes 25 percent of inflow from 8,310 acres and 90 percent of that from 1,370 acres of directly tributary mountains, 50 percent of inflow from directly tributary hills, 10 percent of surface inflow from Arlington Basin, and 5 percent of precipitation on valley land.

TABLE 189. SURFACE OUTFLOW FROM TEMESCAL BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year peirod*
Estimated, originating in			
Temescal Creek [a]	2,410	1,110	1,340
Directly tributary mountains	690	550	540
Directly tributary hills	300	310	310
Inflow from other basins	200	200	210
Precipitation on valley land	1,000	1,050	1,040
Total	4,600	3,220	3,440
To Santa Ana Narrows Basin	220	180	180
To Chino Basin	4,380	3,040	3,260

[a] Storm outflow only, from above Station 15985.

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow must, in accordance with principles set forth in Chapter V have averaged 8,770 acre-feet annually during the 11-year period, as derived in Table 190. Since neither overdraft nor excess is considered to exist there is no change in storage over a long period of time, subsurface outflow in the 32- and 21-year periods, under present conditions, averages 13,000 and 11,600 acre-feet, respectively. Since the latter value is the more conservative it is considered to be the long-time mean annual subsurface outflow.

The greater part of above so-called ''subsurface outflow'' consists of water rising to the surface in the lower portion of the basin, and actually leaving the basin as surface outflow in Temescal Creek or drainage ditches. However, it all originates in ground water within the basin, and for purposes of this study it is immaterial whether it be termed rising water or subsurface outflow.

TABLE 190. ESTIMATED SUBSURFACE OUTFLOW FROM TEMESCAL BASIN[a]

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Water entering basin			
Precipitation	20,720	21,760	21,560
Surface inflow	12,260	8,690	7,400
Import	15,420	15,420	14,550
Subsurface inflow	3,000	3,000	3,000
Subtotal	51,400	48,870	46,510
Increase in storage	0	0	270
Water leaving basin other than subsurface outflow			
Surface outflow	4,600	3,220	3,440
Consumptive use	33,800	34,050	32,760
Export	0	0	1,270
Subtotal	38,400	37,270	37,740
SUBSURFACE OUTFLOW [a]—to Chino Basin	13,000	11,600	8,770

[a] Includes rising water in lower portion of basin.

CHINO BASIN (16)

Chino Basin occupies most of the westerly portion of Upper Santa Ana Valley, and covers about 237 square miles. It is bounded on the southwest and west by Puente Hills and Spadra Basin, on the northwest by Pomona and Claremont Heights Basins, on the north by Cucamonga Basin and San Gabriel Mountains, on the northeast and east by Rialto Basin, and on the southeast and south by Riverside and Temescal Basins and granitic hills. Topography of most of the surface is relatively smooth, with a slope generally southward toward Santa Ana River, ranging from 500 or more feet per mile near heads of well-defined alluvial cones of smaller streams which enter from mountains on the north, to 40 feet per mile below the City of Chino. In its southerly four or five miles the surface is irregular, finally dropping abruptly about 25 feet to bottom lands along Santa Ana River and Chino Creek. Elevations range from 470 feet near Prado, to 2,750 feet at the northerly extremity of the basin. Soils are mostly lighter members of the Hanford and Tujunga series, with heavier members of the Chino and Antioch series extending five or six miles northward from Santa Ana River at Prado. The Hanford and Tujunga soils are quite absorbent, the Chino less so, and the Antioch relatively impervious.

Municipal development occupies about 6 percent of the area, 40 percent is devoted to irrigated agriculture, and about 20 percent to unirrigated grapes. The remainder is in a more or less natural state.

The local water supply, utilized to a minor extent through diversion from surface streams, but more through pumping from ground water, originates in precipitation on valley land, inflow from 9,600 acres of mountains and 21,460 acres of hills directly tributary to the basin, and inflow both underground and on the surface from Claremont Heights, Pomona, Cucamonga, Rialto and Temescal Basins and Riverside-Arlington Area. Imported water provides a large addition to the supply.

A considerable part of surface inflow and precipitation flows out into Santa Ana Narrows Basin, together with some underflow, while there is small surface outflow to Riverside Basin, and underflow to Spadra Basin. Water is exported in small amount to Cucamonga and Arlington Basins. Sewage outflow, to Puente Basin, is also small.

Long-time mean annual net supply under present conditions is less than present annual demand, so an overdraft exists. Evaluation of items required * to estimate its amount follows.

Inflow

Estimated annual surface inflow to the basin averages 100,790 acre-feet, 72,760 acre-feet and 68,490 acre-feet in the 32-, 21- and 11-year periods, respectively, as derived in Table 191.

Inflow from directly tributary mountain area in Day Canyon, was measured at Station 18561 in 1927-28 and since 1929-30. Mean values for all periods are estimated by comparison with San Antonio Creek.

The estimate of 32-year mean annual inflow from the remaining 6,450 acres of mountains directly tributary to the basin is based on the assumption that average annual consumptive use thereon is 18 inches. The 11-year value is estimated to be 0.79 times the 32-year mean, this being the ratio between 11- and 32-year mean annual discharges of Santa Ana River. The corresponding ratio for the 21-year period is 0.80. Inflow from the hills is estimated to be 10 percent of precipitation on them.†

Inflow on the surface from other basins includes all surface outflow from Cucamonga Basin, and a part of that from Claremont Heights, Pomona, Rialto and Temescal Basins and Riverside-Arlington Area. Subsurface inflow includes all underflow out of Pomona, Cucamonga, Rialto and Temescal Basins, and a part of that from Claremont Heights Basin and Riverside-Arlington Area, and averages 26,890 acre-feet, 25,490 acre-feet and 22,660 acre-feet during the 32-, 21- and 11-year periods, respectively.

* Values of change in storage and precipitation are presented in Tables 5 and 7.

† If inflow from hills is assumed to follow the same regimen of flow as in Santa Ana River, average annual inflow from that source is 2,060 and 2,030 acre-feet during the 21- and 11-year periods, respectively.

TABLE 191. INFLOW TO CHINO BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive; 21-year period, 1922-23 to 1942-43, inclusive; and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	32-year period	*21-year period*	*11-year period*
Surface inflow			
From directly tributary mountains			
Measured during part of period	4,260	4,030	3,690
Estimated [a]	5,880	4,710	4,650
From directly tributary hills			
Estimated [a]	2,570	2,600	2,540
From other basins			
Claremont Heights	1,950	2,000	2,980
Pomona	390	390	380
Cucamonga	1,390	1,080	1,200
Rialto	1,970	1,880	1,820
Riverside-Arlington Area	78,000	53,030	47,970
Temescal	4,380	3,040	3,260
TOTAL SURFACE INFLOW	100,790	72,760	68,490
Subsurface inflow, from other basins			
Claremont Heights	500	500	500
Pomona	520	520	520
Cucamonga	760	760	760
Rialto	6,560	6,560	6,560
Riverside-Arlington Area	5,550	5,550	5,550
Temescal [b]	13,000	11,600	8,770
TOTAL SUBSURFACE INFLOW	26,890	25,490	22,660

[a] Includes a relatively small amount of underflow.
[b] Includes rising water in lower portion of Temescal Basin.

Import

In Table 192 estimated imports of water for each year since 1927-28 are presented. There is no import of sewage. Water is imported from both gravity and pumped sources in Claremont Heights, Pomona, Cucamonga, Rialto, and Lytle Basins, and in Colton-Reche Canyon and Riverside-Arlington Areas. Prior to 1934-35 some was imported from Temescal Basin. During the 11-year period import from all sources averaged 39,150 acre-feet annually.

Estimated average annual import under present conditions is 42,040 acre-feet. That from Claremont Heights, Pomona and Cucamonga Basins, and from Colton-Reche Canyon and Riverside-Arlington Areas, and pumped water from Rialto Basin is assumed to equal the average for the four-year period, 1941-42 to 1944-45, inclusive. The remainder of that from Rialto Basin has correlation with diversions from Lytle Creek, and is estimated to equal average annual import from that source for the period of record, 1927-28 to date, multiplied by the ratio between average annual diversion from Lytle Creek during the 21-year period, and during the period of dual record. Present average annual import from Lytle Basin is based upon the calculated amount which can be exported from that basin without exceeding safe yield.

TABLE 192. IMPORT TO CHINO BASIN

Year	Acre-feet	Year	Acre-feet	Year	Acre-feet
1927-28	40,990	1933-34	37,660	1939-40	40,040
1928-29	39,020	1934-35	31,700	1940-41	36,520
1929-30	38,350	1935-36	41,370	1941-42	40,870
1930-31	38,320	1936-37	39,890	1942-43	48,980
1931-32	41,640	1937-38	43,070	1943-44	53,820
1932-33	38,600	1938-39	42,610	1944-45	49,960

Consumptive Use

In Table 193 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942, and by the County of San Bernardino in 1940 are presented. Unit consumptive use is discussed in Chapter V. Portions of the cities of Pomona and Rialto, and all of Ontario, Upland, Chino, Cucamonga and Fontana, together with several smaller communities, overlie the basin. Irrigated crops are diversified, with citrus occupying higher ground, deciduous dominating the intermediate belt, and garden and field crops the lower lands. Of unirrigated land, roughly one-third is devoted to grapes, the remainder being covered in higher portions by moderately heavy brush, ranging to grass and weeds in lower areas. Along Santa Ana River and the lower reaches of Chino Creek there is a considerable area of water-loving vegetation.

TABLE 193. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN CHINO BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley and folded area					
Garden and field	1.4	16,922 [a]	23,691	16,922 [a]	23,691
Avocado and citrus	2.6	22,252	57,855	22,667	58,934
Deciduous	2.3	13,264	30,507	14,394	33,106
Alfalfa	3.0	7,392 [a]	22,176	7,393 [a]	22,179
Water-loving vegetation [b]	4.0	4,726 [a]	18,904	4,727 [a]	18,908
Domestic and industrial	1.8	7,695	13,851	8,770	15,786
Unirrigated	----	79,487	----	76,865	----
32-year period	1.3	----	----	----	99,924
21-year period	1.305	----	----	----	100,309
11-year period	1.292	----	102,697	----	----
Subtotal	----	151,738	----	151,738	----
32-year period	----	----	----	----	272,528
21-year period	----	----	----	----	272,913
11-year period	----	----	269,681	----	----
Hill area					
Garden and field	0.3 [c]	139	42	289	87
Avocado and citrus	1.4 [c]	134	188	134	188
Deciduous	1.2 [c]	202	242	202	242
Alfalfa	1.9 [c]	84	160	84	160
Domestic and industrial	0.7 [c]	216	151	216	151
Subtotal	----	775	783	925	828
Grand total	----	152,513	----	152,663	----
32-year period	----	----	----	----	273,356
21-year period	----	----	----	----	273,741
11-year period	----	----	270,464	----	----

[a] Average of 1932 and 1942 surveys.
[b] Includes about 100 acres of irrigated grass.
[c] Difference between irrigated culture and natural vegetation.

Export

In Table 194 estimated exports of water and sewage for each year since 1927-28 are presented. Water from both gravity and pumped sources is exported to Riverside-Arlington Area and Cucamonga Basin, while sewage goes to Puente Basin. During the 11-year period an annual average of 1,380 acre-feet of water and 550 acre-feet of sewage was exported, a total of 1,930 acre-feet.

Estimated average annual export of water under present conditions is 1,710 acre-feet, and of sewage 1,110 acre-feet, a total of 2,820 acre-feet. The values for water and for sewage are equal to the historic average for the four-year period, 1941-42 to 1944-45, inclusive, and the 1944-45 value, respectively.

TABLE 194. EXPORT FROM CHINO BASIN

(Acre-feet)

Year	Water	Sewage	Year	Water	Sewage
1927-28	1,600	430	1936-37	1,760	700
1928-29	1,440	480	1937-38	1,830	690
1929-30	1,420	480	1938-39	1,570	690
1930-31	1,580	530	1939-40	1,600	710
1931-32	1,440	530	1940-41	1,580	760
1932-33	390	490	1941-42	1,480	870
1933-34	1,040	530	1942-43	1,700	1,050
1934-35	1,310	610	1943-44	1,940	1,110
1935-36	1,340	610	1944-45	1,740	1,110

Surface Outflow During 11-Year Period

Estimated surface outflow from Chino Basin averages 83,570 acre-feet annually. Of this 83,330 acre-feet is to Santa Ana Narrows Basin, and is the difference between measured discharge at Station 15822 and estimated inflow to that basin between its upper boundary and the station. The remaining 240 acre feet is to Riverside-Arlington Area, and the estimate is based on the assumption that within the area tributary to Station 16953, 50 percent of the inflow from Rialto Basin, 75 percent of the inflow from 1,310 acres of tributary hills and 1 percent of the precipitation on 6,750 acres of valley land in Chino Basin enters Santa Ana River above that station.

Subsurface Outflow to Santa Ana Narrows Basin

In 1939, during early stages of construction of Prado Dam on Santa Ana River, Paul Bailey, Engineer for Orange County Water District, conducted experiments to determine underflow at or just upstream from the dam site. From measurements of extractions of water from deep pits across the canyon floor, and observation of water table fluctuations in a series of test wells, he concluded that underflow was greater than 2.75 second-feet, but less than 4.00 second-feet.

It is believed that the true value of subsurface outflow to Santa Ana Narrows Basin is somewhat less than the average of the above two observations, and an estimated annual value of 2,400 acre-feet is used herein for both 11-year and long-time average subsurface outflow at Prado.

Subsurface Outflow to Spadra Basin

Assuming that all items involved have been correctly evaluated, subsurface outflow to Spadra Basin during the 11-year period, must, in accordance with principles set forth in Chapter V, have averaged 710 acre-feet annually, as derived in Table 195. It is improbable that the actual subsurface outflow at this point is any less than this, and it is probably not significantly greater so far as evaluation of overdraft is concerned. A decrease of 0.1 foot in value of unit consumptive use assigned garden and field crops in Chino Basin alone would increase derived subsurface outflow by about 1,700 acre-feet, with no change in estimated overdraft. A similar decrease in value for avocado and citrus would increase calculated outflow by 2,250 acre-feet, and decrease estimated overdraft by only about 40 acre-feet.

TABLE 195. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM CHINO TO SPADRA BASINS DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	205,960	
Surface inflow	68,490	
Subsurface inflow	22,660	
Import	39,150	
Water coming from storage in basin	22,810	
Total		359,070
Water leaving basin, other than by underflow to Spadra Basin		
Surface outflow	83,570	
Subsurface outflow	2,400	
Export	1,930	
Consumptive use	270,460	
Total		358,360
SUBSURFACE OUTFLOW—to Spadra Basin		710

Rising Water Originating in Chino Basin

Discharge of Santa Ana River, measured at Station 15822 near Prado throughout the 11-year period, averaged 84,760 acre-feet annually. It included all inflow to the river originating in runoff from mountains and hills tributary to Santa Ana Narrows Basin above the station, surface and subsurface inflow from Temescal Basin and Riverside-Arlington Area, water flowing across the surface of Chino Basin, and rising water from Chino Basin. All of these items but the last two are evaluated in discussion of the basins involved. Surface outflow from Chino Basin in Santa Ana River, other than rising water and that originating in above-named basins, includes part of the inflow from directly tributary mountains and hills, runoff originating in precipitation on valley and folded land overlying the basin, and part of the outflow from Claremont Heights, Pomona, Cucamonga and Rialto Basins.

Inflow from mountains directly tributary to Chino Basin is in small streams which seldom flow far into the basin. The distance from the mouths of their canyons to Santa Ana River averages 15 miles. Spreading grounds on cones below Deer and Day Canyons augment natural percolation from these streams. While the residue is in part carried on paved roads extending southward across the basin, average outflow is relatively small, and is estimated at 5 percent of inflow. The greater part of inflow from directly tributary hills is into Chino Creek, which follows the northeasterly toe of Puente Hills for about 12 miles. Soil flanking these hills is heavy, and in lower reaches of the stream the water table is near the surface. Inflow from hills west of Riverside soon reaches the river. Outflow in Santa Ana River of water originating in the directly tributary hills is estimated to be 40 percent of the inflow therefrom. Of precipitation on valley land overlying Chino Basin, 1 percent is estimated to reach Santa Ana River at Station 15822 as outflow, together with 5 percent of precipitation on folded lands. Inflow from Claremont Heights Basin is in San Antonio Creek, which flows in an unpaved channel about seven miles to the upper reaches of Chino Creek. That from Pomona Basin crosses the boundary in streets and small channels, which carry it either to San Antonio or Chino Creeks. Outflow in Santa Ana River from these two basins is estimated at 40 percent of inflow. Inflow from Cucamonga Basin is in Cucamonga Creek, which in times of great flood, flows in a poorly-defined channel 10 miles south to Santa Ana River. Inflow from Rialto Basin is in several small channels which enter the basin about 12 miles from the river. Only 5 percent of inflow from Cucamonga and Rialto Basins is estimated to reach Prado.

Subtracting the sum of all other increments, as shown in Table 196, from the measured surface discharge at Prado gaging station, results in an estimated increment of rising water originating in Chino Basin which averages 17,910 acre-feet annually during the 11-year period. This is the net value after all consumptive use along the river between Riverside Narrows and the lower boundary of the basin has been subtracted.

TABLE 196. ESTIMATED AVERAGE ANNUAL RISING WATER ORIGINATING IN CHINO BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Surface discharge in Santa Ana River at Prado		84,760
Inflow to Santa Ana River below Riverside Narrows		
From mountains and hills tributary to Santa Ana Narrows Basin	1,250	
From Temescal Basin		
To Santa Ana Narrows Basin	180	
To Chino Basin		
Surface	3,260	
Subsurface [a]	8,770	
From Riverside-Arlington Area		
At Riverside Narrows		
Surface	47,170	
Subsurface	500	
Near Arlington, surface	800	
From Chino Basin, excluding rising water		
Originating in directly tributary mountains	420	
Originating in directly tributary hills	1,020	
Originating in precipitation on valley and folded land	2,000	
Originating in surface inflow from other basins		
Claremont Heights	1,190	
Pomona	150	
Cucamonga	60	
Rialto	80	
Subtotal		66,850
RISING WATER ORIGINATING IN CHINO BASIN		17,910

[a] Includes rising water in lower portion of Temescal Basin.

Long-time Average Annual Surface Outflow

During any considerable period of time there is no net change in storage in the immediate vicinity of Santa Ana River between Riverside Narrows and Prado. Therefore during the 32- and 21-year periods all water which enters the river between those points and is not consumed there must flow out of Chino Basin into Santa Ana Narrows Basin, either in or beneath the river. This includes flow across the surface of Chino Basin from the north, the basis for estimate of which is stated in the preceding article, rising water originating in Chino Basin which is assumed the same in all three periods, and surface and subsurface inflow from Riverside-Arlington Area and Temescal Basin which have been evaluated as outflow from those areas. Of this, 2,400 acre-feet leaves Chino Basin as underflow, and the remainder, averaging 116,040 acre-feet annually in the 32-year period and 88,300 acre-feet in the 21-year period, flows out in Santa Ana River. Assuming the ratio of runoff to precipitation to be the same in the 32- and 21-year periods as during the 11-year period, estimated surface outflow from Chino Basin to Riverside-Arlington Area averages 240 acre-feet and 250 acre-feet, respectively, in the two periods.

Twenty-one year mean annual discharge at Prado gaging station under present conditions, estimated on the above basis, is 89,770 acre-feet, as compared with the historic 21-year mean of 97,890 * acre-feet. Consumptive use in basins upstream from the station has increased, and some water has come out of storage during the 21-year period, so the comparison provides a check on the assumptions made.

TABLE 197. ESTIMATED SURFACE OUTFLOW FROM CHINO BASIN

Average annual for 32-year period, 1904-05 to 1935-36, inclusive, and 21-year period, 1922-23 to 1942-43, inclusive

(Acre-feet)

	32-year period	*21-year peirod*
To Santa Ana Narrows Basin		
Estimated, originating in		
Directly tributary mountains	510	440
Directly tributary hills	1,030	1,040
Precipitation on valley and folded land	2,020	2,040
Rising water originating in Chino Basin	17,910	17,910
Surface inflow from other basins		
Claremont Heights	780	800
Pomona	160	160
Cucamonga	70	50
Rialto	80	90
Riverside-Arlington Area		
At Riverside Narrows	77,230	52,220
Near Arlington	770	810
Temescal	4,380	3,040
Subsurface inflow from other basins		
Riverside-Arlington Area	500	500
Temescal	13,000	11,600
TOTAL	118,440	90,700
Subsurface	2,400	2,400
Surface outflow at Prado	116,040	88,300
To Riverside-Arlington Area		
Surface, originating in		
Surface inflow from Rialto Basin	120	130
Directly tributary hills	30	30
Precipitation on valley land	90	90
Total surface outflow to Riverside-Arlington Area	240	250
TOTAL SURFACE OUTFLOW—from Chino Basin	116,280	88,550

Overdraft

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual overdraft is 17,780 acre-feet, as derived in Table 198. If 32-year mean values are substituted in the table, the derived overdraft is 17,360 acre-feet.

* Measured discharge corrected for inflow between stations 15822 and 15851A since 1940-41.

TABLE 198. ESTIMATED ANNUAL OVERDRAFT IN CHINO BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period	----	----	----	22,810
Items tending to increase the drop				
Consumptive use	273,740	270,460	3,280	
Export	2,820	1,930	890	
Surface outflow	88,550	83,570	4,980	
Subsurface outflow	3,110	3,110	0	
Subtotal to be added				9,150
Items tending to decrease the drop				
Precipitation	210,150	205,960	4,190	
Import	42,040	39,150	2,890	
Surface inflow	72,760	68,490	4,270	
Subsurface inflow	25,490	22,660	2,830	
Subtotal to be subtracted				14,180
OVERDRAFT				17,780

IRVINE BASIN (33d)

Irvine Basin * occupies the extreme southeasterly portion of the Coastal Plain, and covers about 46 square miles. It is bounded on the northeast by foothills of Santa Ana Mountains, on the southeast by South Coastal Basin boundary, on the southwest and south by San Joaquin Hills, on the west by East Coastal Plain Pressure Area, and on the northwest by Santa Ana Forebay Area. Topography of most of the surface is smooth, with slope generally toward the west averaging 80 feet per mile. Along bordering hills and in the extreme southeasterly portion it is more irregular, with a somewhat steeper slope toward the axis of the valley. Elevations range from 15 to 600 feet above sea level. Soils covering the surface range from lighter members of the Hanford series through Ramona sandy loam to Yolo clay adobe. The last is quite impervious. Domestic development occupies about 2 percent of the area, about 63 percent is devoted to agriculture, and the remainder is in a more or less natural state. Irrigated culture is about evenly divided between garden and field crops, and orchards, the greater part of the latter being citrus.

The local water supply, utilized almost entirely through pumping from ground water, originates in precipitation on valley lands, inflow from 25,240 acres of hills directly tributary to the basin, and inflow on the surface from Santa Ana Forebay Area. Imported water provides a relatively large addition to the supply.

* There is no physical barrier to movement of ground water into the pressure area, and the classification as a separate basin is for convenience only.

A considerable part of surface inflow and runoff originating in precipitation on the valley flows out into the pressure area of East Coastal Plain, together with relatively large underflow. A small amount of water is exported to Santa Ana Forebay Area, and there is some sewage outflow to the ocean.

In this basin, long-time mean annual net supply under present conditions is less than present annual demand, so an overdraft exists. Evaluation of items required * to estimate its amount follows.

Inflow

Assuming that 10 percent of precipitation on the hills runs off, estimated annual inflow from 25,240 acres of hills directly tributary to the basin averages 3,390 acre-feet during the 21-year period, and 3,290 acre-feet during the 11-year period.† Estimated annual inflow on the surface from Santa Ana Forebay Area averages 490 acre-feet in the 21-year period, and 480 acre-feet during the 11-year period. Total estimated inflow from all sources averages 3,880 and 3,770 acre-feet annually in the respective periods. Subsurface inflow, other than that relatively small amount included with surface inflow from the hills, is considered negligible.

Import

In Table 199 estimated imports of water for each year since 1927-28 are presented. There is no import of sewage. Water is imported from East Coastal Plain Pressure Area, Santa Ana Forebay Area, Santiago Basin, and from Colorado River, and is from both gravity and pumped sources. During the 11-year period an annual average of 7,300 acre-feet was imported, of which 2,510 acre-feet was from Santiago Creek and Reservoir.

It is estimated that average annual import of water under present conditions is 9,440 acre-feet. Average annual import from Santa Ana Forebay Area under present conditions is assumed to equal the historic average for the four-year period, 1941-42 to 1944-45, inclusive. That from Colorado River and from East Coastal Plain Pressure Area is assumed the same as in 1944-45. Import from Santiago Basin consists of diversions from Santiago Reservoir and Creek, and from Fremont Canyon. The estimate of that from the reservoir is based on an operation study carried through the 21-year period, and on established rights to releases. Average annual import by diversion from Fremont Canyon and from Santiago Creek below the reservoir is assumed to equal the historic average for the 13-year period, 1932-33 to 1944-45, inclusive.

TABLE 199. IMPORT TO IRVINE BASIN

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	6,680	1933-34	8,600	1939-40	8,870
1928-29	5,130	1934-35	5,820	1940-41	9,290
1929-30	5,270	1935-36	7,350	1941-42	11,810
1930-31	5,330	1936-37	8,980	1942-43	10,620
1931-32	5,990	1937-38	11,830	1943-44	10,720
1932-33	9,280	1938-39	11,080	1944-45	10,670

* Values of change in storage and precipitation, also required, are presented in Tables 5 and 7.

† If runoff from hills is assumed to follow the same regimen of flow as Santa Ana River, average annual inflow from that source for the 11-year period is 3,330 acre-feet.

Consumptive Use

In Table 200 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit values are discussed in Chapter V. A small part of the City of Santa Ana and all of Tustin overlie the basin. Light brush, weeds and grass cover the unused lands.

TABLE 200. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN IRVINE BASIN

Type of culture	Unit consumptive use, feet	1932 Acres	1932 Acre-feet	1942 Acres	1942 Acre-feet
Valley area					
Garden and field	1.3	3,785	4,920	9,380	12,194
Avocado and citrus	1.9	7,396	14,052	7,933	15,073
Deciduous	1.7	1,666	2,832	1,289	2,191
Alfalfa	2.5	45	112	0	0
Domestic and industrial	1.4	599	839	619	867
Unirrigated	----	16,205	----	10,475	----
21-year period	0.9	----	----	----	9,428
11-year period	0.886	----	14,358	----	----
Subtotal	----	29,696	----	29,696	----
21-year period	----	----	----	----	39,753
11-year period	----	----	37,113	----	----
Hill area					
Garden and field	0[a]	30	0	30	0
Avocado and citrus	0.7[a]	312	218	342	239
Subtotal	----	342	218	372	239
Grand total	----	30,038	----	30,068	----
21-year period	----	----	----	----	39,992
11-year period	----	----	37,331	----	----

[a] Difference between irrigated culture and natural vegetation.

Export

In Table 201 estimated exports of water and sewage for each year since 1927-28 are presented. Water is exported to Santa Ana Forebay Area, while sewage goes directly to the ocean. During the 11-year period an annual average of 140 acre-feet of water and 180 acre-feet of sewage was exported, a total of 320 acre-feet.

Estimated average annual export of water under present conditions is 160 acre-feet, and of sewage 300 acre-feet, a total of 460 acre-feet. It is assumed that the historic export during the four-year period, 1941-42 to 1944-45, inclusive, and that during 1944-45 alone, represent present average annual exports of water and sewage, respectively.

TABLE 201. EXPORT FROM IRVINE BASIN

(Acre-feet)

Year	Water	Sewage	Year	Water	Sewage
1927-28	150	180	1936-37	160	220
1928-29	150	180	1937-38	120	240
1929-30	150	170	1938-39	130	250
1930-31	150	170	1939-40	90	250
1931-32	160	170	1940-41	100	230
1932-33	140	160	1941-42	40	220
1933-34	100	160	1942-43	210	260
1934-35	140	190	1943-44	220	310
1935-36	110	190	1944-45	160	300

Surface Outflow

Outflow on the surface includes part of the inflow from directly tributary hills, part of that from Santa Ana Forebay Area and runoff originating in precipitation on the overlying valley. Assuming that 50 percent of inflow from directly tributary hills, 75 percent of inflow from Santa Ana Forebay Area, and 5 percent of precipitation on overlying valley land leave the basin, estimated outflow averages 3,830 acre-feet and 3,720 acre-feet in the 21- and 11-year periods, respectively, as derived in Table 202.

TABLE 202. SURFACE OUTFLOW FROM IRVINE BASIN

Average annual for 21-year period, 1922-23 to 1942-43, inclusive, and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	21-year period	11-year period
Estimated, originating in		
Directly tributary hills	1,700	1,650
Inflow from other basins	370	360
Precipitation on valley and folded land	1,760	1,710
Total	3,830	3,720

Overdraft

Assuming that the 21-year period is the cycle of long-time mean supply, estimated annual overdraft is 2,740 acre-feet, as derived in Table 203.

TABLE 203. ESTIMATED ANNUAL OVERDRAFT IN IRVINE BASIN UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period	----	----	----	3,120
Items tending to increase the drop				
Consumptive use	39,990	37,330	2,660	
Export	460	320	140	
Surface outflow	3,830	3,720	110	
Subtotal to be added				2,910
Items tending to decrease the drop				
Precipitation	35,200	34,160	1,040	
Surface inflow	3,880	3,770	110	
Import	9,440	7,300	2,140	
Subtotal to be subtracted				3,290
OVERDRAFT				2,740

Subsurface Outflow

Assuming that all items involved have been correctly evaluated, subsurface outflow during the 11-year base period, must in accordance with principles set forth in Chapter V, have averaged 6,980 acre-feet annually, as derived in Table 204.

TABLE 204. ESTIMATED AVERAGE ANNUAL SUBSURFACE OUTFLOW FROM IRVINE BASIN DURING THE 11-YEAR PERIOD, 1927-28 TO 1937-38, INCLUSIVE

	Acre-feet	
Water entering basin		
Precipitation	34,160	
Surface inflow	3,770	
Import	7,300	
Water coming from storage in basin	3,120	
Subtotal		48,350
Water leaving basin on surface		
Surface outflow	3,720	
Exported water	140	
Exported sewage	180	
Consumptive use	37,330	
Subtotal		41,370
SUBSURFACE OUTFLOW—to East Coastal Plain Pressure Area		6,980

LOWER SANTA ANA RIVER AREA

Santa Ana Forebay Area (33c)
East Coastal Plain Pressure Area (33f)
Yorba Linda Basin (35)
Santa Ana Narrows Basin (37)
Santiago Basin (50)

There is no physical barrier to movement of ground water from Santa Ana Narrows and Santiago Basins into Santa Ana Forebay Area, or from the forebay area into East Coastal Plain Pressure Area. A large part of the supply to Yorba Linda Basin is imported from Santa Ana Narrows Basin. Because of these natural or artificial interconnections between its component parts, the group of basins comprising the Lower Santa Ana River Area is treated as a unit.

Topography of most of the area, including nearly all of Santa Ana Forebay Area and the pressure area is relatively smooth, with average slope of less than 20 feet per mile. The direction of slope changes gradually from westerly in the vicinity of the boundary between Santa Ana Forebay Area and Yorba Linda Basin, to southerly in the vicinity of Santa Ana. Topography of Yorba Linda Basin is rolling and irregular. In Santa Ana Narrows Basin relatively smooth bottom lands are bordered by steeply sloping alluvium flanking the hills on either side. In Santiago Basin topography is generally rolling, but rougher than in Yorba Linda Basin. Elevations range from sea level to 1,100 feet above. Virtually all of Santa Ana Forebay Area west of Santa Ana River is covered with soils of the Hanford series. Farther south extensive areas of the finer textured Chino soils appear. East of the river Yolo soils predominate, with considerable areas of Ramona soils on mesa lands nearer the coast. In Yorba Linda and Santiago Basins, Yolo and Ramona soils, both only moderately permeable, predominate. In Santa Ana Narrows Basin these soils cover the steeper lands, and lighter Hanford soils the bottom lands. Municipal development occupies about 8 percent of the area, about 60 percent is covered by irrigated crops, and the remainder is either in a natural state or temporarily lying fallow.

This area resembles Lower Los Angeles and San Gabriel Rivers Area in that downward percolation into the pumping aquifers of East Coastal Plain Pressure Area is negligible. The local water supply, utilized by both large gravity diversions and extensive pumping from the ground water, originates in precipitation on the valley, inflow from 42,670 acres of mountains and 53,250 acres of hills directly tributary to the non-pressure portion of the area, surface inflow from La Habra, Chino and Temescal Basins, and subsurface inflow from Chino Basin. Some water is imported, the greater part of it for municipal use.

While a large part of the inflow is rising water in Santa Ana River, regulated in upstream ground water basins to a fairly uniform flow, there is still considerable outflow onto the pressure area and thence to the ocean. Water and sewage are exported from the nonpressure portion of the area in relatively large amount.

For Lower Santa Ana River Area as a whole, long-time mean net supply under present conditions is less than present annual demand, so an overdraft exists. In estimating the amount of this overdraft significant items are change in storage, precipitation on, and surface inflow and import to the nonpressure portion of the area; surface outflow, consumptive use and export leaving the nonpressure portion; and extraction from the pressure area. Evaluation of each of these items * follows.

Inflow to Nonpressure Portion of Area

Since deep percolation in the pressure area is negligible, only that inflow entering the nonpressure portion of the area is here considered. Estimated annual surface inflow averages 110,280 acre-feet and 102,860 acre-feet in the 21-year and 11-year periods, respectively, as derived in Table 205.

None of the inflow from directly tributary mountains and hills is measured at point of entry. Assuming, however, that precipitation on valley lands tributary to Santiago Creek above Station 15728 is balanced by consumptive use on those lands and underflow at the station, metered discharge at the station, corrected for upstream diversions and regulation, measures the inflow from mountains and hills above that point. The estimate of inflow from the remaining 6,050 acres of mountains and 40,440 acres of hills is based on the assumption that 10 percent of the precipitation thereon runs off. Inflow from Chino and Temescal Basins in Santa Ana River and from La Habra Basin in Brea and East Fullerton Creeks, is discussed in connection with outflow from the respective basins.

Subsurface inflow, other than that indicated by note in Table 205, is from Chino Basin and is estimated to amount to 2,400 acre-feet annually.

TABLE 205. SURFACE INFLOW TO NONPRESSURE PORTION OF LOWER SANTA ANA RIVER AREA

Average annual for 21-year period, 1922-23 to 1942-43, inclusive, and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	21-year period	*11-year period*
From directly tributary mountains and hills		
Measured during part of period	14,320	12,300
Estimated [a]	6,240	6,050
From other basins		
La Habra	1,240	1,000
Chino and Temescal	88,480	83,510
Total	110,280	102,860

[a] Includes a relatively small amount of underflow.

Import to Nonpressure Portion of Area

In Table 206 estimated values of import of water from East Coastal Plain Pressure Area, from Irvine and La Habra Basins, and from Colorado River to the nonpressure portion of Lower Santa Ana River Area for each year since 1927-28, are presented. There is no import of sewage. During the 11-year period an average of 1,320 acre-feet was imported annually.

Assuming that the historic average annual imports from La Habra and Irvine Basins during the four-year period, 1941-42 to 1944-45, inclu-

* Values of change in storage and precipitation are presented in Tables 5 and 7.

sive, and the 1944-45 imports from Colorádo River and from East Coastal Plain Pressure Area represent average annual imports under present conditions, the value so estimated is 4,680 acre-feet.

TABLE 206. IMPORT TO NONPRESSURE PORTION OF LOWER SANTA ANA RIVER AREA

Year	*Acre-feet*	*Year*	*Acre-feet*	*Year*	*Acre-feet*
1927-28	1,400	1933-34	1,220	1939-40	1,300
1928-29	1,360	1934-35	1,210	1940-41	2,440
1929-30	1,410	1935-36	1,270	1941-42	1,940
1930-31	1,420	1936-37	1,290	1942-43	2,370
1931-32	1,330	1937-38	1,310	1943-44	2,690
1932-33	1,250	1938-39	1,340	1944-45	4,690

Consumptive Use in Nonpressure Portion of Area

In Table 207 estimates of consumptive use based on culture surveys conducted by the Division of Water Resources in 1932 and 1942 are presented. Unit values are discussed in Chapter V. The Cities of Anaheim and Orange, and portions of Santa Ana and Fullerton, overlie the area. Acreage devoted to crops other than citrus is relatively very small. Unirrigated lands are covered for the most part with grass and weeds, with water-loving vegetation bordering the river in Santa Ana Narrows Basin.

TABLE 207. ESTIMATED AVERAGE ANNUAL CONSUMPTIVE USE IN NONPRESSURE PORTION OF LOWER SANTA ANA RIVER AREA

Type of culture	*Unit consumptive use, feet*	*1932*		*1942*	
		Acres	*Acre-feet*	*Acres*	*Acre-feet*
Valley and folded area					
Garden and field	1.3	1,454	1,890	1,249	1,624
Avocado and citrus	1.9	43,986	83,573	45,343	86,152
Deciduous	1.7	4,200	7,140	2,480	4,216
Alfalfa and irrigated grass	2.5	146	365	256	640
Domestic and industrial	1.4	4,109	5,753	4,284	5,998
River-bed brush (water-loving)	4.0	1,100	4,400	1,100	4,400
Unirrigated	----	17,479	----	17,762	----
21-year period	0.9	----	----	----	15,986
11-year period	0.886	----	15,486	----	----
Evaporation from Santiago Reservoir [a]	----	----	540	----	1,050
Subtotal	----	72,474	----	72,474	----
21-year period	----	----	----	----	120,066
11-year period	----	----	119,147	----	----
Hill Area					
Garden and field	0.0 [b]	95	0	85	0
Avocado and citrus	0.7 [b]	1,163	814	1,198	839
Domestic and industrial	0.2 [b]	38	8	98	20
Subtotal	----	1,296	822	1,381	859
Grand total	----	73,770	----	73,855	----
21-year period	----	----	----	----	120,925
11-year period	----	----	119,969	----	----

[a] Difference between evaporation from water surface and rainfall on reservoir surface.
[b] Difference between irrigated culture and natural vegetation.

Export From Nonpressure Portion of Area

In Table 208 estimated values of exports of water and sewage from the nonpressure portion of Lower Santa Ana River Area for each year since 1927-28 are presented. Water is exported to Irvine Basin and to East Coastal Plain Pressure Area, and sewage goes directly to the ocean. During the 11-year period an annual average of 9,270 acre-feet of water and 3,120 acre-feet of sewage was exported, a total of 12,390 acre-feet.

Export of water from Santiago Basin to Irvine Basin consists of diversions from Santiago Creek and Reservoir, and from Fremont Canyon. Based upon a study of operation of Santiago Reservoir for the 21-year period, and upon established rights to releases from the reservoir, estimated export available annually from that source under present conditions averages 4,330 acre-feet. Average annual export by diversion from Fremont Canyon, and from Santiago Creek below the reservoir, is assumed to equal its historic average for the 13-year period, 1932-33 to 1944-45, inclusive. Mean annual export from Santa Ana Forebay Area to Irvine Basin and the pressure area is assumed the same as its historic average for the four-year period, 1941-42 to 1944-45, inclusive. Average annual sewage outflow under present conditions is assumed equal to its historic value for 1944-45. Estimated total annual export from the nonpressure portion of the area under present conditions is 16,390 acre-feet, consisting of 11,240 acre-feet of water, and 5,150 acre-feet of sewage.

TABLE 208. EXPORT FROM NONPRESSURE PORTION OF LOWER SANTA ANA RIVER AREA
(Acre-feet)

Year	Water	Sewage	Year	Water	Sewage
1927-28	9,000	2,660	1936-37	10,700	3,960
1928-29	6,890	2,920	1937-38	13,640	4,800
1929-30	7,100	2,800	1938-39	12,830	4,660
1930-31	7,150	2,810	1939-40	10,550	4,650
1931-32	7,640	2,910	1940-41	10,620	4,720
1932-33	11,900	2,640	1941-42	14,060	4,830
1933-34	11,090	2,670	1942-43	12,670	4,600
1934-35	7,250	2,960	1943-44	12,410	5,070
1935-36	9,590	3,160	1944-45	12,050	5,150

Surface Outflow From Nonpressure Portion of Area

Outflow on the surface includes part of the inflow from directly tributary mountains and hills, a part of that from La Habra, Chino and Temescal Basins, and runoff originating in precipitation on overlying valley and folded land. It is estimated to average 25,510 acre-feet and 21,450 acre-feet annually in the 21- and 11-year periods, respectively, as derived in Table 209.

While some error on the conservative side is no doubt introduced by so doing, it is assumed that long-time mean annual outflow in the river under present conditions is represented by the historical average annual flow, measured at Station 14495 during all but the first three months of the 21-year period. Studies indicate that operation of Prado Reservoir, completed in 1940, has reduced the annual discharge at Santa Ana little if any. Had Santiago Reservoir, completed in December, 1931, been in operation throughout the period, it is estimated that 21-year mean annual discharge at Station 15728 would have been reduced by about 1,000 acre-feet. Percolation between that station and Station 14495 would, however, also have been reduced, and inflow somewhat increased by cultural changes. The error introduced by assuming historical 21-year average and present long-time mean annual to be identical is therefore small.

It is assumed that total discharge of East Fullerton Creek, measured at Stations 15611 or 1192 since 1930-31, and of Brea Creek, measured at Stations 1171 or 1172 during the same period, flows out of the nonpressure portion of the area. Runoff in these creeks prior to 1930-31 is estimated from its relationship with precipitation as represented by the Coastal Plain Group.

From that part of Santa Ana Forebay Area which is tributary to Irvine Basin, outflow is estimated to consist of 90 percent of inflow from directly tributary hills, and 5 percent of precipitation on valley land. From the remainder of the forebay area not tributary to gaging stations, outflow is estimated as 5 percent of precipitation on valley land. Additional outflow from the nonpressure portion of the area consists of an estimated 25 percent of unmeasured inflow to Santa Ana Forebay Area from Yorba Linda Basin. Such inflow is estimated as 10 percent of precipitation on hills, and 5 percent of that on valley and folded land.

TABLE 209. SURFACE OUTFLOW FROM NONPRESSURE PORTION OF LOWER SANTA ANA RIVER AREA

Average annual for 21-year period, 1922-23 to 1942-43, inclusive, and 11-year period, 1927-28 to 1937-38, inclusive

(Acre-feet)

	21-year period	*11-year period*
Measured during all or part of period		
Santa Ana River	21,070	17,350
East Fullerton Creek	460	430
Brea Creek	1,020	800
Estimated, originating in		
Directly tributary hills	720	700
Precipitation on valley and folded land	2,240	2,170
Total	25,510	21,450

Extractions From East Coastal Plain Pressure Area

Under the procedure followed in estimating the difference between present and 11-year average extractions from the pressure area as set forth in Table 210, a decrease of 20 acre-feet has occurred. While use of water within the area has increased, the introduction in 1943-44 of Colorado River water to the service areas of the City of Santa Ana and South Coast Municipal Utility District has balanced the increased demand.

A relatively small part of the total extraction has been measured, but this portion includes that of the principal municipal and industrial producers whose 1944-45 extractions were significantly different than those of the 11-year period. These are presented first in the table.

Acreage devoted to garden and field crops, constituting nearly two-thirds of the irrigated land in East Coastal Plain Pressure Area, has varied from year to year during and since the 11-year period, but has demonstrated no consistent trend. Acreage in citrus and alfalfa increased consistently until 1937-38, and has since remained almost constant, while deciduous acreage has decreased consistently during and since the 11-year period. In the second part of the table, the change in acreage between 1932 and 1942, assumed to represent the difference between the average for the 11-year period and the present value, respectively, is multiplied by the estimated average duty for each of the three crops in which a consistent change has occurred.

TABLE 210. ESTIMATED DIFFERENCE BETWEEN 11-YEAR AVERAGE AND PRESENT ANNUAL EXTRACTIONS FROM EAST COASTAL PLAIN PRESSURE AREA

			11-year average, acre-feet	*1944-45, acre-feet*	*Decrease, acre-feet*
Measured extractions					
Municipalities			5,510	3,120	2,390
Districts and water companies			3,540	3,870	—330
Industrial users			1,660	1,770	—110
Cadet Center			0	400	—400
Decrease in measured extractions					1,550
	Acres served				
	1932	*1942*	*Decrease*	*Duty, feet*	
Unmeasured extractions					
Citrus	12,811	13,669	—858	1.3	—1,120
Alfalfa	5,599	6,109	—510	1.8	—920
Deciduous	1,181	546	635	0.8	510
Decrease in unmeasured extractions					—1,530
Total decrease in extractions					20

Subsurface Outflow From East Coastal Plain Pressure Area

While the boundary between East Coastal Plain Pressure Area and Central Coastal Plain does not follow a physical barrier to movement of ground water, contours of the water table indicate that very little ground water crosses the general course of Coyote Creek in either direction. Creation of a gradient sufficient to produce appreciable underflow could only result from excessive lowering of the water table on the downstream side of the selected boundary. Such lowering did not occur during or since the 11-year period, nor is it considered probable that it will occur in the future. Contours of the water table adjacent to the ocean indicate that subsurface outflow in that direction, during and since the 11-year period, has been negligible.

Overdraft

Assuming that the 21-year period represents a cycle of long-time mean supply, estimated annual overdraft is 10,240 acre-feet, as derived in Table 211.

TABLE 211. ESTIMATED ANNUAL OVERDRAFT IN LOWER SANTA ANA RIVER AREA UNDER PRESENT CONDITIONS ASSUMING THE 21-YEAR PERIOD, 1922-23 TO 1942-43, INCLUSIVE, TO BE ONE OF LONG-TIME MEAN SUPPLY

(Acre-feet)

	Estimated long-time mean annual under present conditions	*Actual 11-year base period average annual*	*Difference*	
Average annual drop in storage during base period				14,690
Items tending to increase the drop				
Nonpressure portion of area				
Consumptive use	120,920	119,970	950	
Export	16,390	12,390	4,000	
Surface outflow	25,510	21,450	4,060	
Pressure area				
Extractions	----	----	—20	
Subsurface outflow	----	----	0	
Subtotal to be added				8,990
Items tending to decrease the drop				
Nonpressure portion of area				
Precipitation	89,460	86,800	2,660	
Surface inflow	110,280	102,860	7,420	
Import	4,680	1,320	3,360	
Subtotal to be subtracted				13,440
OVERDRAFT				10,240

PUBLICATIONS

DIVISION OF WATER RESOURCES

PUBLICATIONS OF THE

DIVISION OF WATER RESOURCES

DEPARTMENT OF PUBLIC WORKS

STATE OF CALIFORNIA

When the Department of Public Works was created in July, 1921, the State Water Commission was succeeded by the Division of Water Rights, and the Department of Engineering was succeeded by the Division of Engineering and Irrigation in all duties except those pertaining to State Architect. Both the Division of Water Rights and the Division of Engineering and Irrigation functioned until August, 1929, when they were consolidated to form the Division of Water Resources. The Water Project Authority was created by the Central Valley Project Act of 1933.

STATE WATER COMMISSION

*First Report, State Water Commission, March 24, to November 1, 1912.
*Second Report, State Water Commission, November 1, 1912, to April 1, 1914.
*Biennial Report, State Water Commission, March 1, 1915, to December 1, 1916.
*Biennial Report, State Water Commission, December 1, 1916, to September 1, 1918.
*Biennial Report, State Water Commission, September 1, 1918, to September 1, 1920.

DIVISION OF WATER RIGHTS

*Bulletin No. 1—Hydrographic Investigation of San Joaquin River, 1920-1923.
*Bulletin No. 2—Kings River Investigation, Water Master's Report, 1918-1923.
*Bulletin No. 3—Proceedings First Sacramento-San Joaquin River Problems Conference, 1924.
*Bulletin No. 4—Proceedings Second Sacramento-San Joaquin River Problems Conference, and Water Supervisors' Report, 1924.
*Bulletin No. 5—San Gabriel Investigation—Basic Data, 1923-1926.
Bulletin No. 6—San Gabriel Investigation—Basic Data, 1926-1928.
Bulletin No. 7—San Gabriel Investigation—Analysis and Conclusions, 1929.
*Biennial Report, Division of Water Rights, 1920-1922.
*Biennial Report, Division of Water Rights, 1922-1924.
Biennial Report, Division of Water Rights, 1924-1926.
Biennial Report, Division of Water Rights, 1926-1928.

DEPARTMENT OF ENGINEERING

*Bulletin No. 1—Cooperative Irrigation Investigations in California, 1912-1914.
*Bulletin No. 2—Irrigation Districts in California, 1887-1915.
Bulletin No. 3—Investigations of Economic Duty of Water for Alfalfa in Sacramento Valley, California, 1915.
*Bulletin No. 4—Preliminary Report on Conservation and Control of Flood Waters in Coachella Valley, California, 1917.
*Bulletin No. 5—Report on the Utilization of Mojave River for Irrigation in Victor Valley, California, 1918.
*Bulletin No. 6—California Irrigation District Laws, 1919 (now obsolete).
Bulletin No. 7—Use of Water from Kings River, California, 1918.
*Bulletin No. 8—Flood Problems of the Calaveras River, 1919.
Bulletin No. 9—Water Resources of Kern River and Adjacent Streams and Their Utilization, 1920.
*Biennial Report, Department of Engineering, 1907-1908.
*Biennial Report, Department of Engineering, 1908-1910.
*Biennial Report, Department of Engineering, 1910-1912.
*Biennial Report, Department of Engineering, 1912-1914.
*Biennial Report, Department of Engineering, 1914-1916.
*Biennial Report, Department of Engineering, 1916-1918.
*Biennial Report, Department of Engineering, 1918-1920.

DIVISION OF WATER RESOURCES

Including Reports of the Former Division of Engineering and Irrigation

*Bulletin No. 1—California Irrigation District Laws, 1921 (now obsolete).
*Bulletin No. 2—Formation of Irrigation Districts, Issuance of Bonds, etc., 1922.
Bulletin No. 3—Water Resources of Tulare County and Their Utilization, 1922.
Bulletin No. 4—Water Resources of California, 1923.
Bulletin No. 5—Flow in California Streams, 1923.
Bulletin No. 6—Irrigation Requirements of California Lands, 1923.
*Bulletin No. 7—California Irrigation District Laws, 1923 (now obsolete).
*Bulletin No. 8—Cost of Water to Irrigators in California, 1925.
Bulletin No. 9—Supplemental Report on Water Resources of California, 1925.
*Bulletin No. 10—California Irrigation District Laws, 1925 (now obsolete).
Bulletin No. 11—Ground Water Resources of Southern San Joaquin Valley, 1927.

* Reports and Bulletins out of print. These may be borrowed by your local library from the California State Library at Sacramento, California.

Bulletin No. 12—Summary Report on the Water Resources of California and a Coordinated Plan for Their Development, 1927.
Bulletin No. 13—The development of the Upper Sacramento River, containing U. S. R. S. Cooperative Report on Iron Canyon Project, 1927.
Bulletin No. 14—The Control of Floods by Reservoirs, 1928.
*Bulletin No.18—California Irrigation District Laws, 1927, Revision.
*Bulletin No. 18-A—California Irrigation District Laws, 1929 Revision.
Bulletin No. 18-B—California Irrigation District Laws, 1931 Revision.
Bulletin No. 18-C—California Irrigation District Laws, 1933 Revision.
Bulletin No. 18-D—California Irrigation District Laws, 1935 Revision.
Bulletin No. 18-E—California Irrigation District Laws, 1937 Revision.
*Bulletin No. 18-F—California Irrigation District Laws, 1939 Revision.
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*Bulletin No. 18-H—Water Code, Divisions 10 and 11, Irrigation District Laws 1943.
Bulletin No. 19—Santa Ana Investigation, Flood Control and Conservation (with packet of maps), 1928.
Bulletin No. 20—Kennett Reservoir Development, an Analysis of Methods and Extent of Financing by Electric Power Revenue, 1929.
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Bulletin No. 21-C—Report on Irrigation Districts in California for the year 1931.
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Bulletin No. 21-M—Report on Irrigation Districts in California for the year 1941.
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Bulletin No. 23—Report on Sacramento-San Joaquin Water Supervisor, 1924-1928.
Bulletin No. 24—A proposed Major Development on American River, 1929.
Bulletin No. 25—Report to Legislature of 1931 on State Water Plan, 1930.
Bulletin No. 26—Sacramento River Basin, 1931.
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Bulletin No. 28-A—Industrial Survey of Upper San Francisco Bay Area, 1930.
Bulletin No. 29—San Joaquin River Basin, 1931.
Bulletin No. 31—Santa Ana River Basin, 1930.
Bulletin No. 32—South Coastal Basin, a Cooperative Symposium, 1930.
Bulletin No. 33—Rainfall Penetration and Consumptive Use of Water in Santa Ana River Valley and Coastal Plain, 1930.
Bulletin No. 34—Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley, 1930.
Bulletin No. 35—Permissible Economic Rate of Irrigation Development in California, 1930.
Bulletin No. 36—Cost of Irrigation Water in California, 1930.
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